

The background of the slide is a composite image. The upper portion shows a deep space scene with a bright, glowing galaxy or nebula against a dark, star-filled sky. A series of thin, purple lines radiate from the top left, representing a particle shower. The lower portion of the image transitions into a view of Earth's surface, showing blue oceans and white, swirling clouds.

The Pierre Auger Observatory

Auger North

- **Science of Auger North (Angela Olinto)**
- **Features of the Auger North Detector**
- **Auger North R&D**
- **Organization**
- **Cost, Schedule and Funding**
- **Fermilab and Auger North**

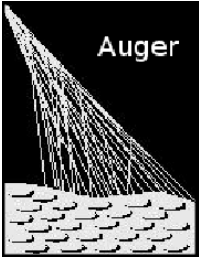


The Pierre Auger Observatory

Auger North

Science Goals:

**To Discover the Sources of
Ultra High Energy Cosmic Rays
To Study Particle Interactions
above 100 TeV CM**

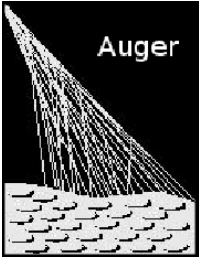


To Discover UHECR Sources need:

Full Sky Distribution of events $> 60 \text{ EeV}$
Much Higher Statistics $> 60 \text{ EeV}$

To Probe $> 100 \text{ TeV}$ scale, need:

Determine the Primary Composition $> 60 \text{ EeV}$:
Astrophysically AND thru Shower Properties
Detect UHE neutrinos and photons



Auger South

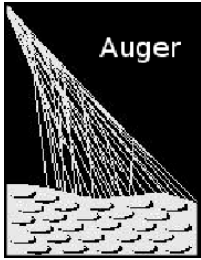
Largest and Best UHECR detector ever built!

Observes UHECRs over a wide energy range:
From 10^{17} eV to 10^{20} eV

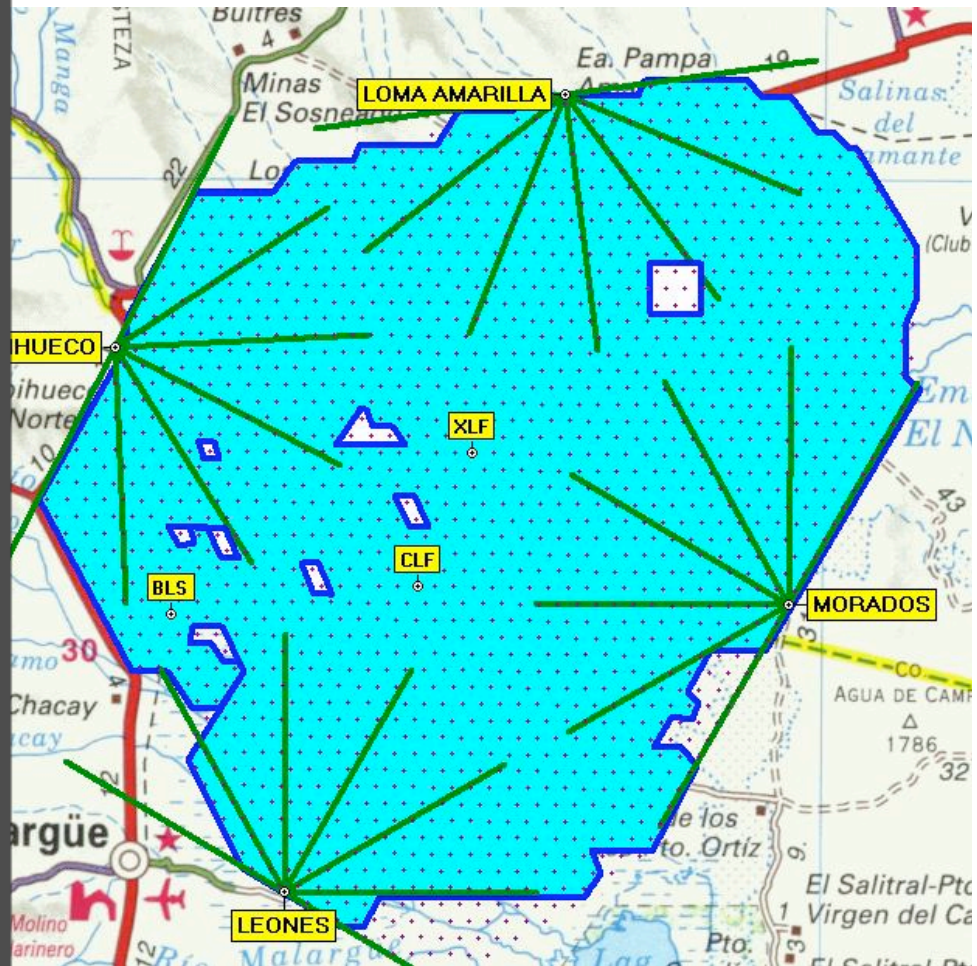
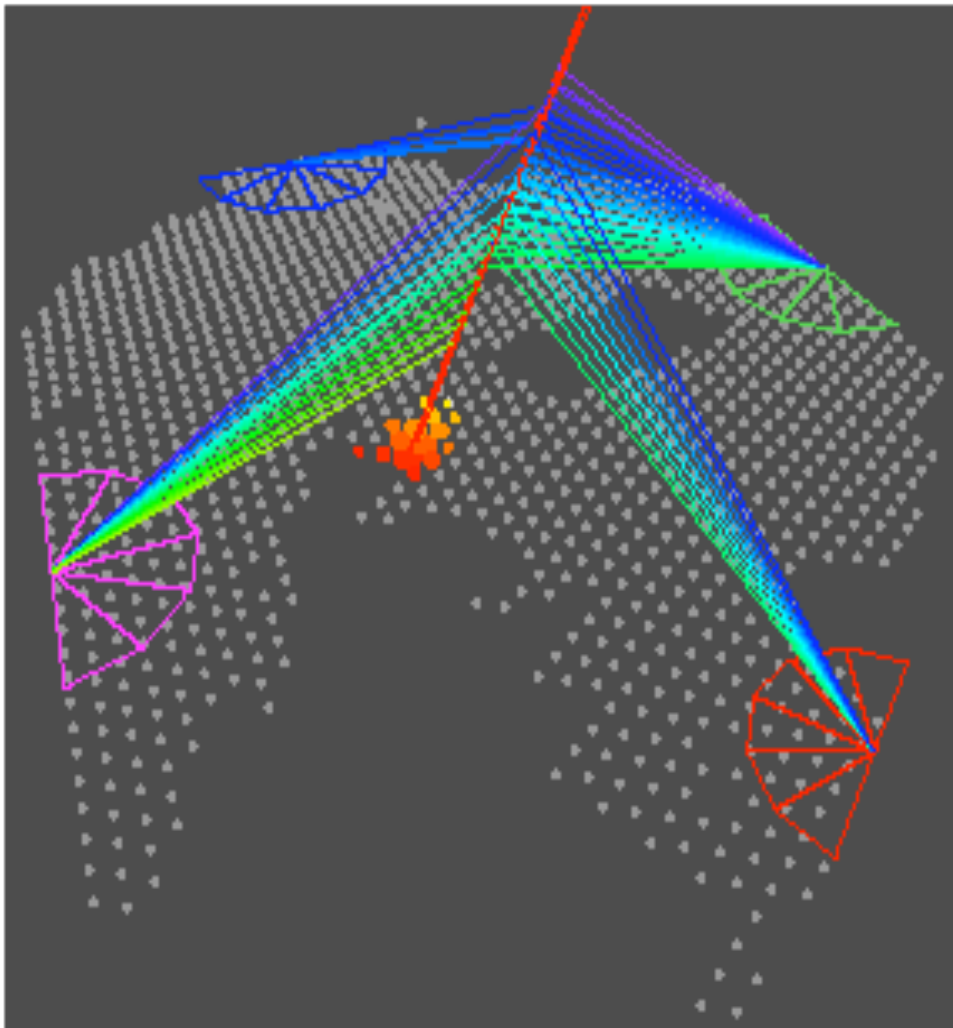
Hybrid Observatory:

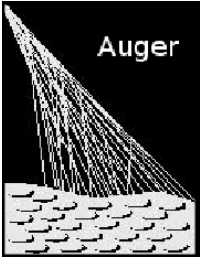
3,000 km² array of water Cherenkov detectors

Fluorescence Telescopes (10% duty)



Auger South





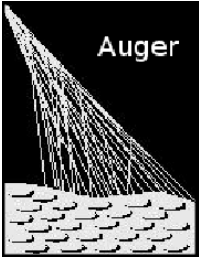
Auger South

Observed the GZK feature in the spectrum

Determined Sky anisotropies > 60 EeV

Showed that the GZK sphere is populated

Strongest UHE tau neutrino and UHE photon limits



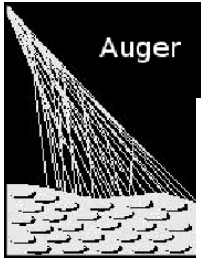
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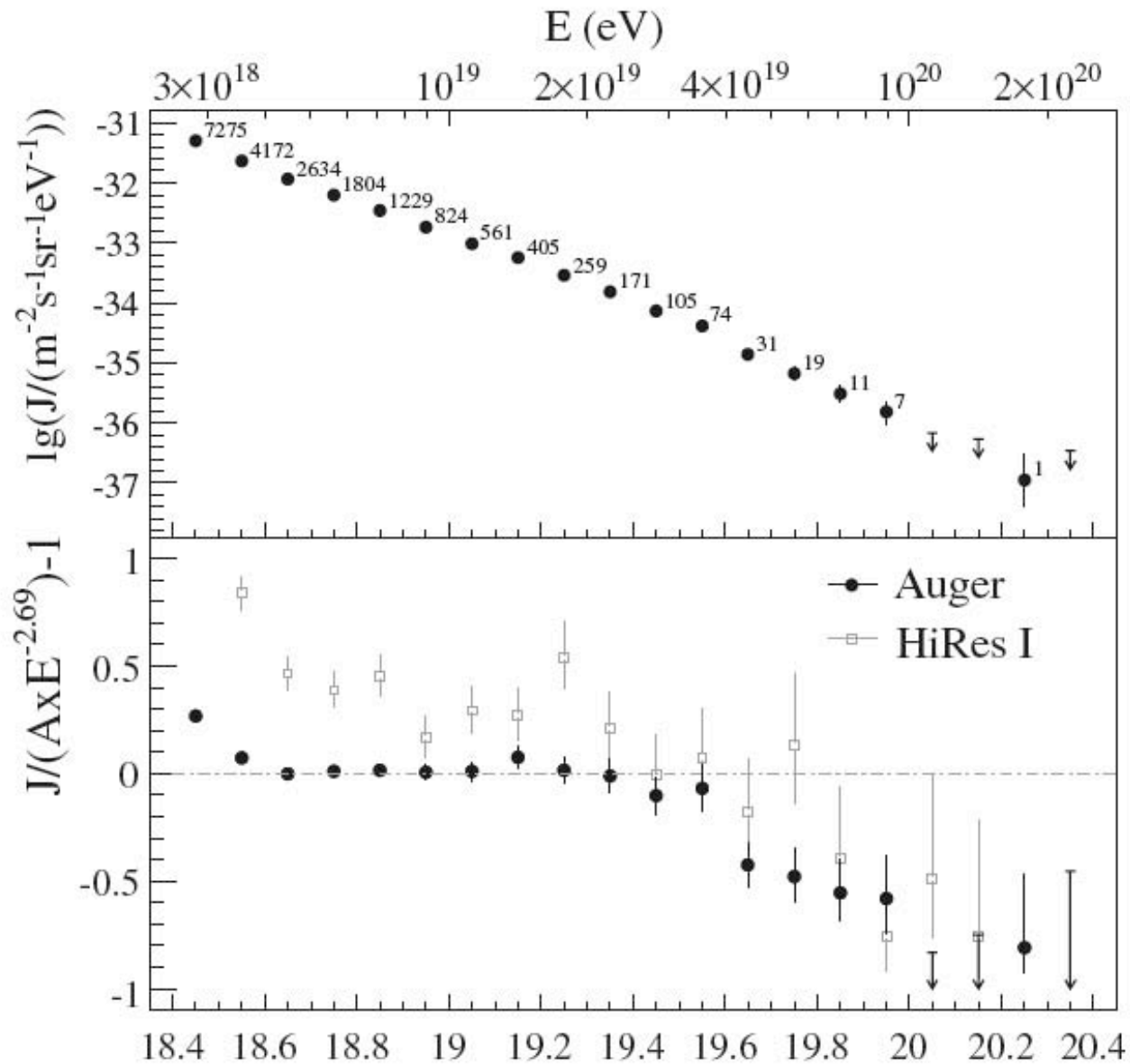
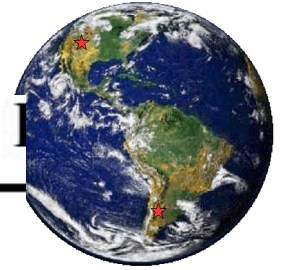
Strongest UHE tau neutrino and UHE photon limits

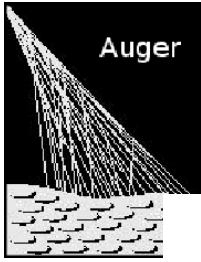


Auger & HiRes spectra

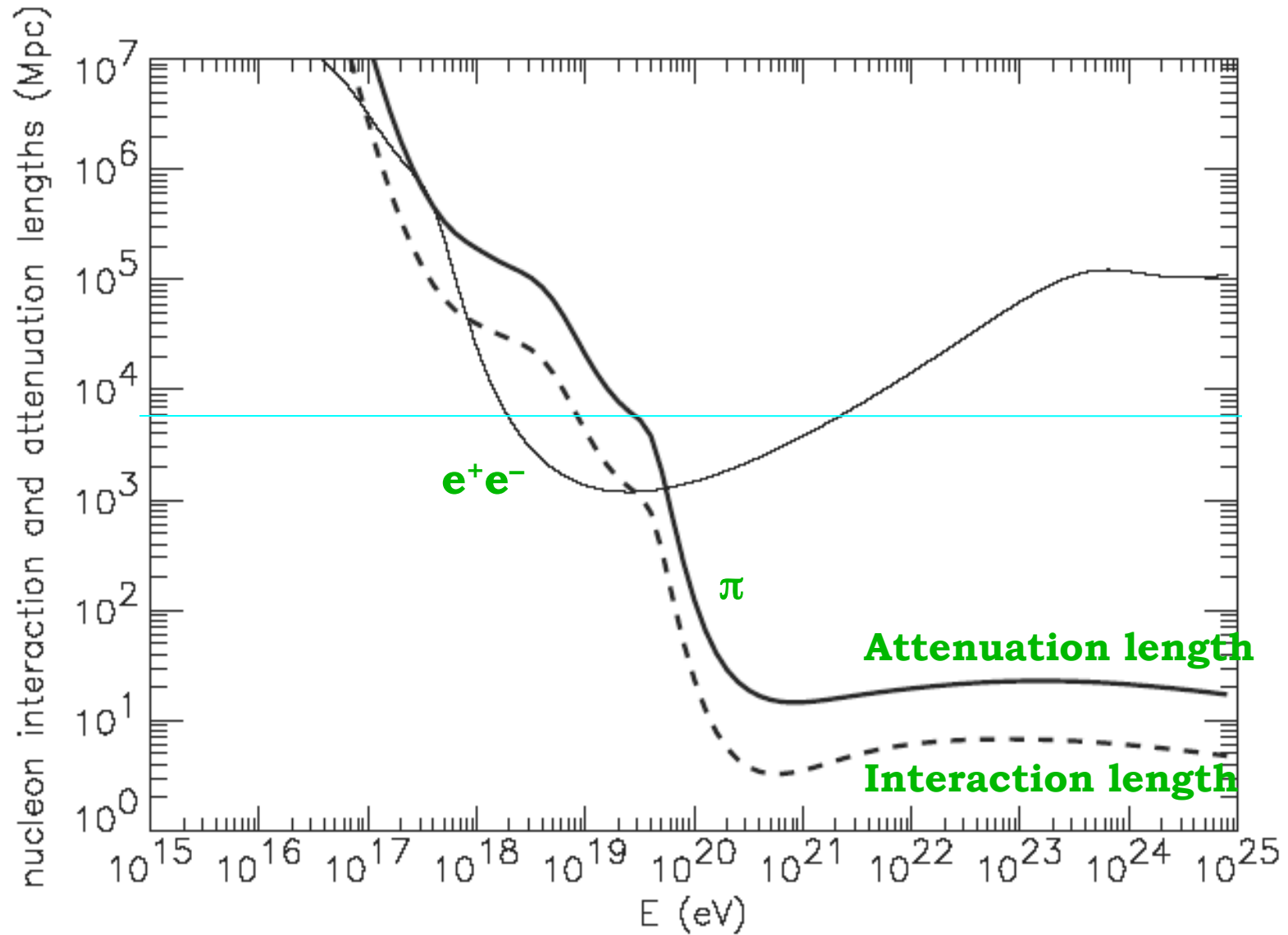
PRL 101, 061101 (2008)

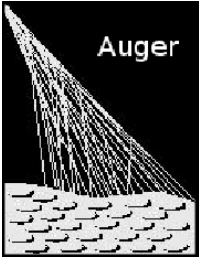
PHYSICAL REVIEW LETTERS



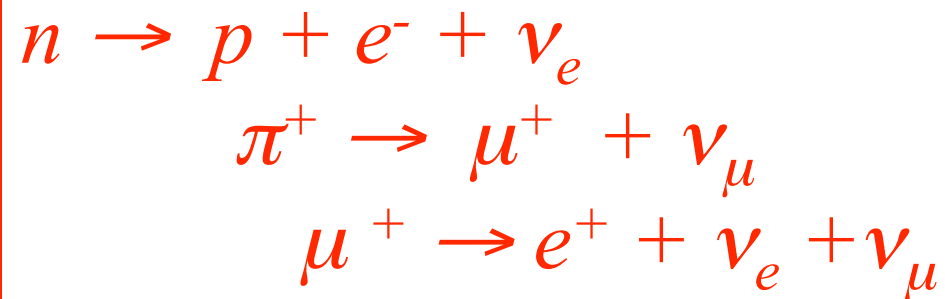
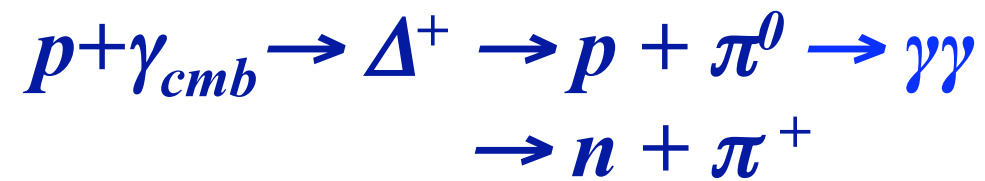


Attenuation length

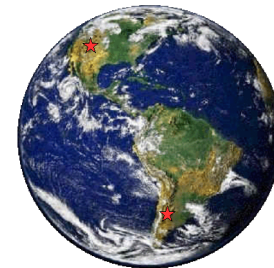
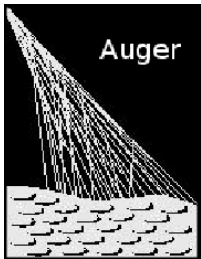




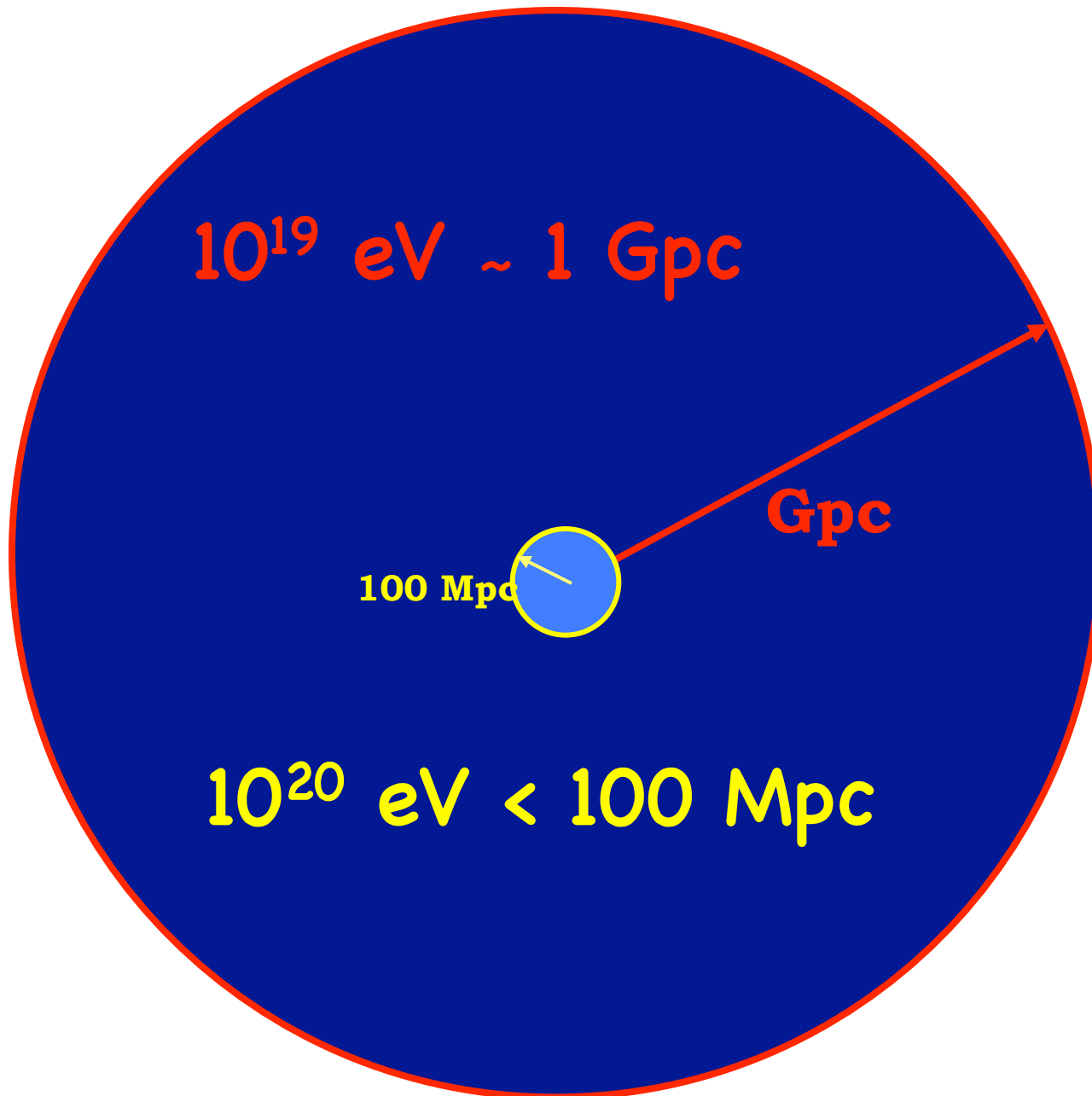
Cosmogenic (GZK) Neutrinos & Photons

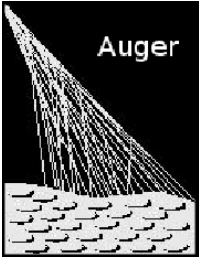


GZK Cutoff – Greisen, Zatsepin, Kuzmin 1966



Horizons:





Horizons:

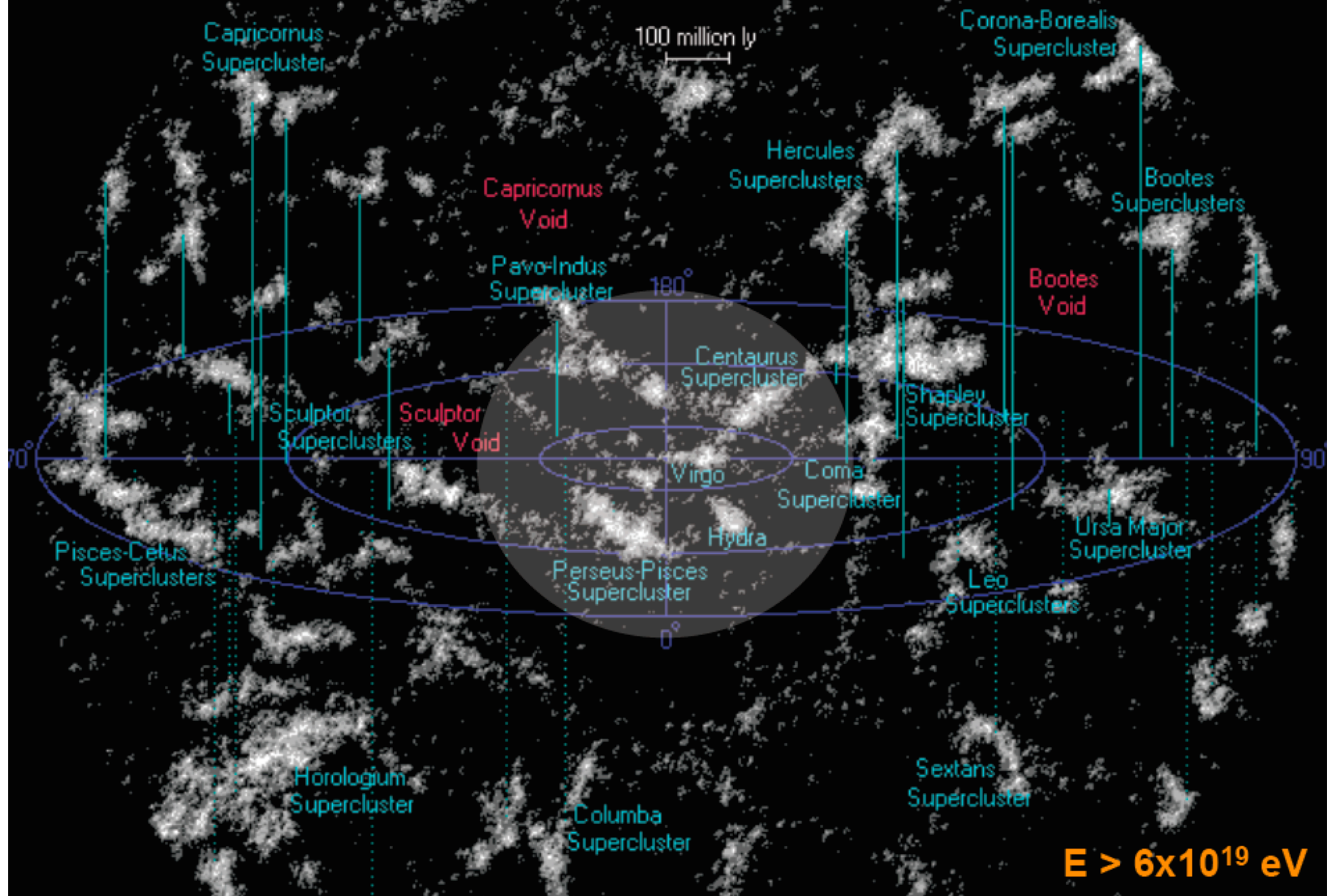
10^{19} eV ~ 1 Gpc

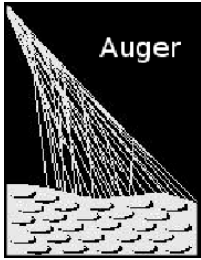
Distance Indicator!!!!

The Ability to Point to Sources!

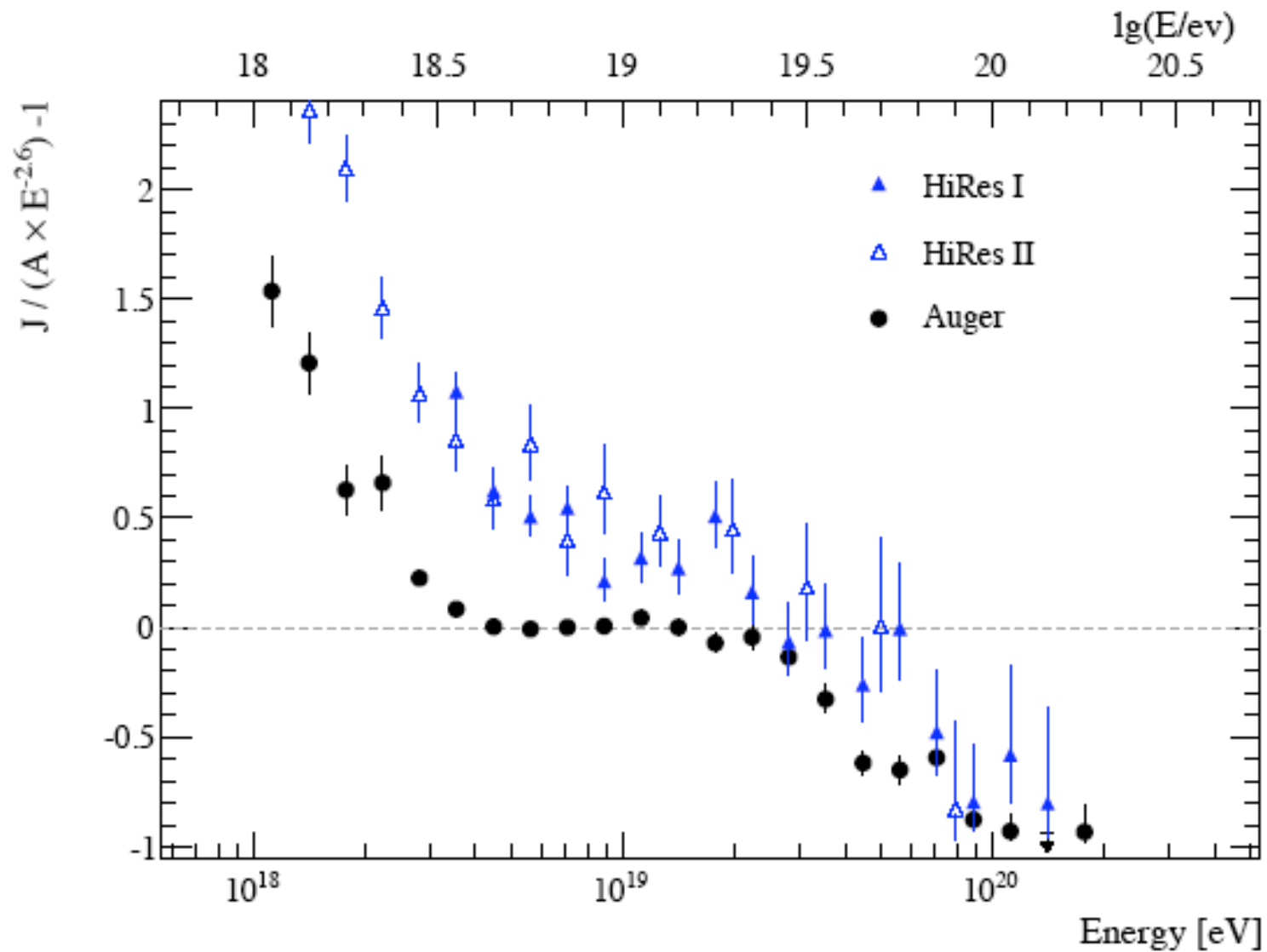
10^{20} eV < 100 Mpc

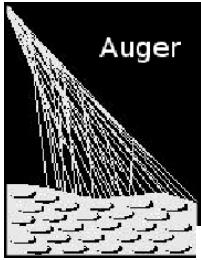
Distribution of Galaxies



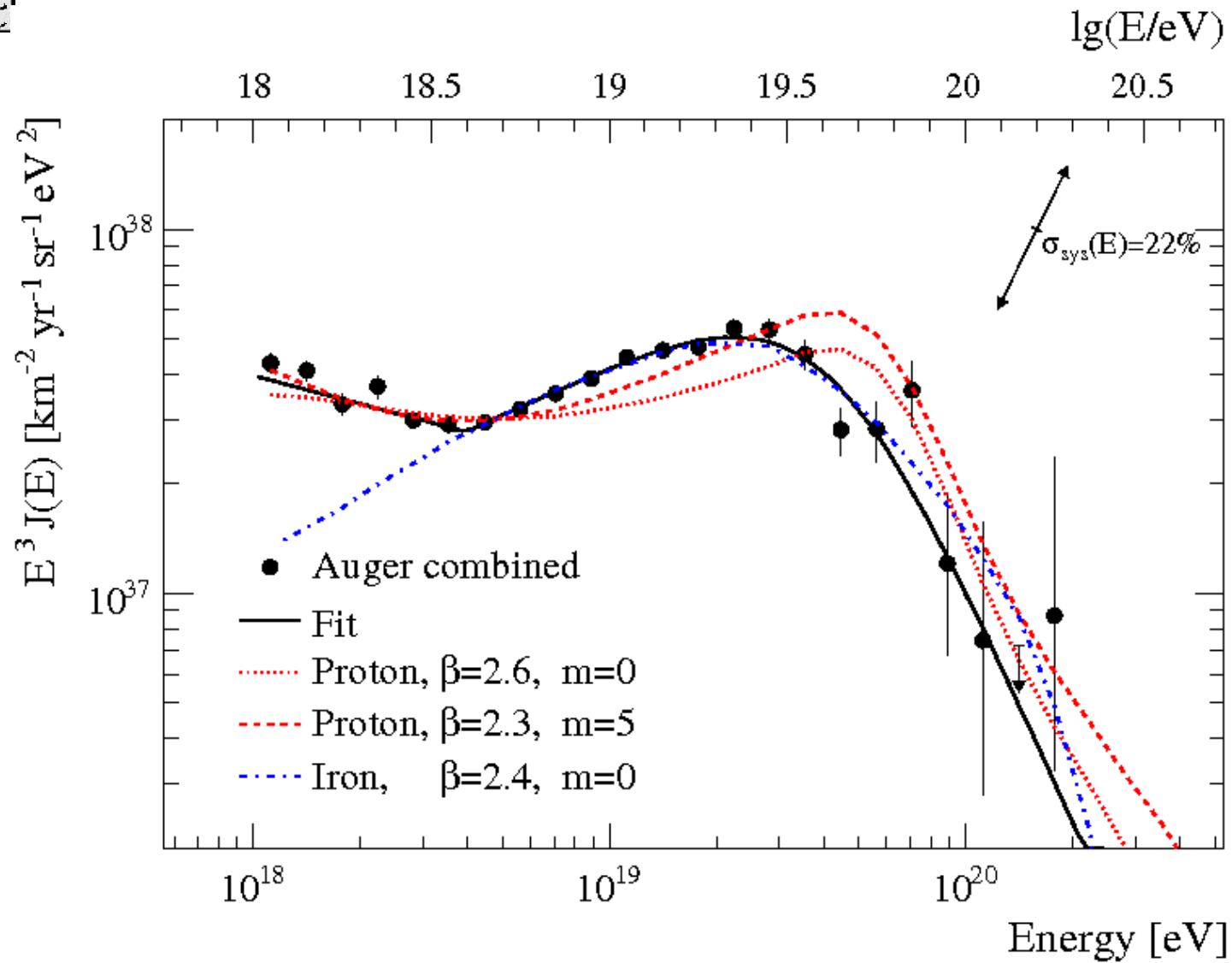


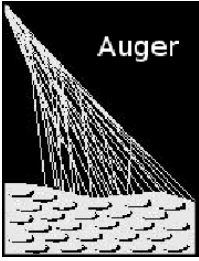
Recent Auger Spectrum





GZK fits to spectrum





Auger South

Observed the GZK feature in the spectrum

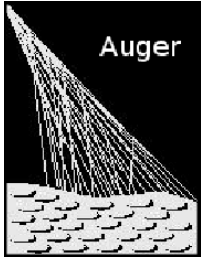
Determined Sky anisotropies > 60 EeV

Showed that the GZK sphere is populated

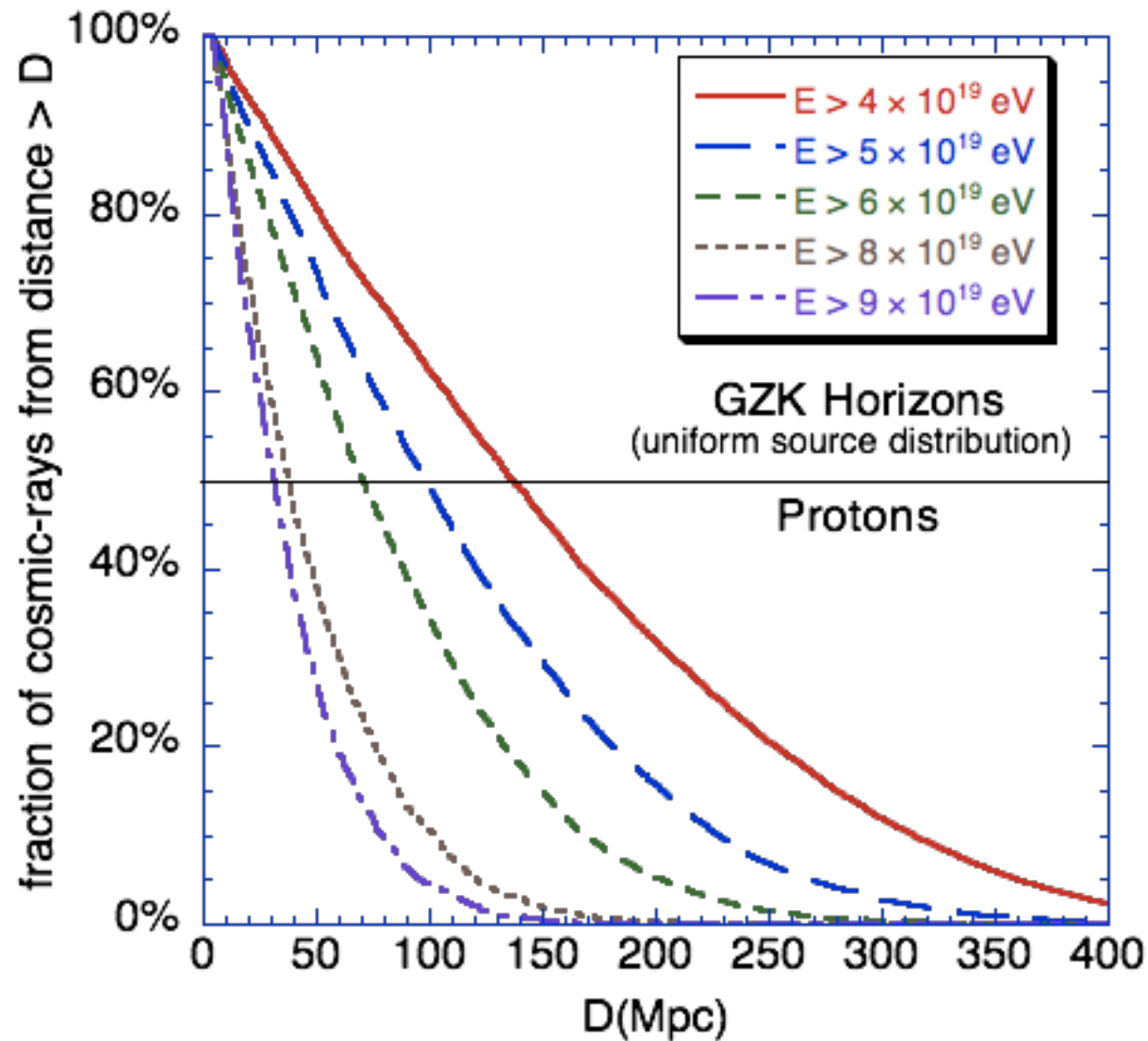
Strongest UHE tau neutrino and UHE photon limits

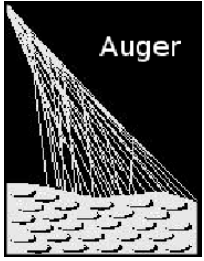


**Top discovery of 2007
in the Physical Sciences
(by Science Magazine)**



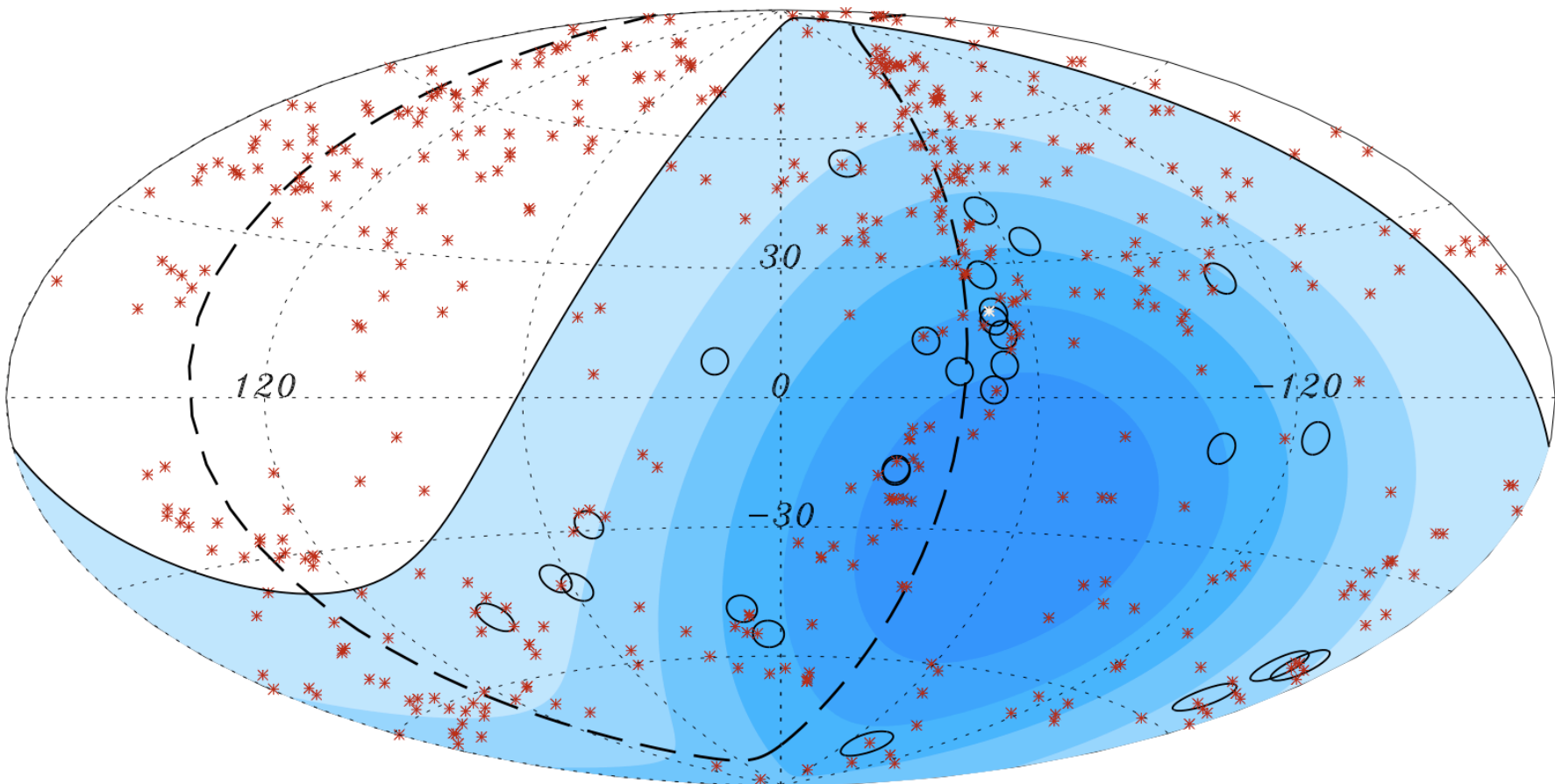
GZK Horizon - Protons

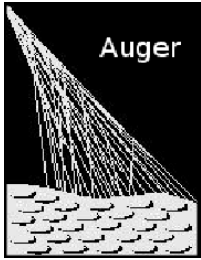




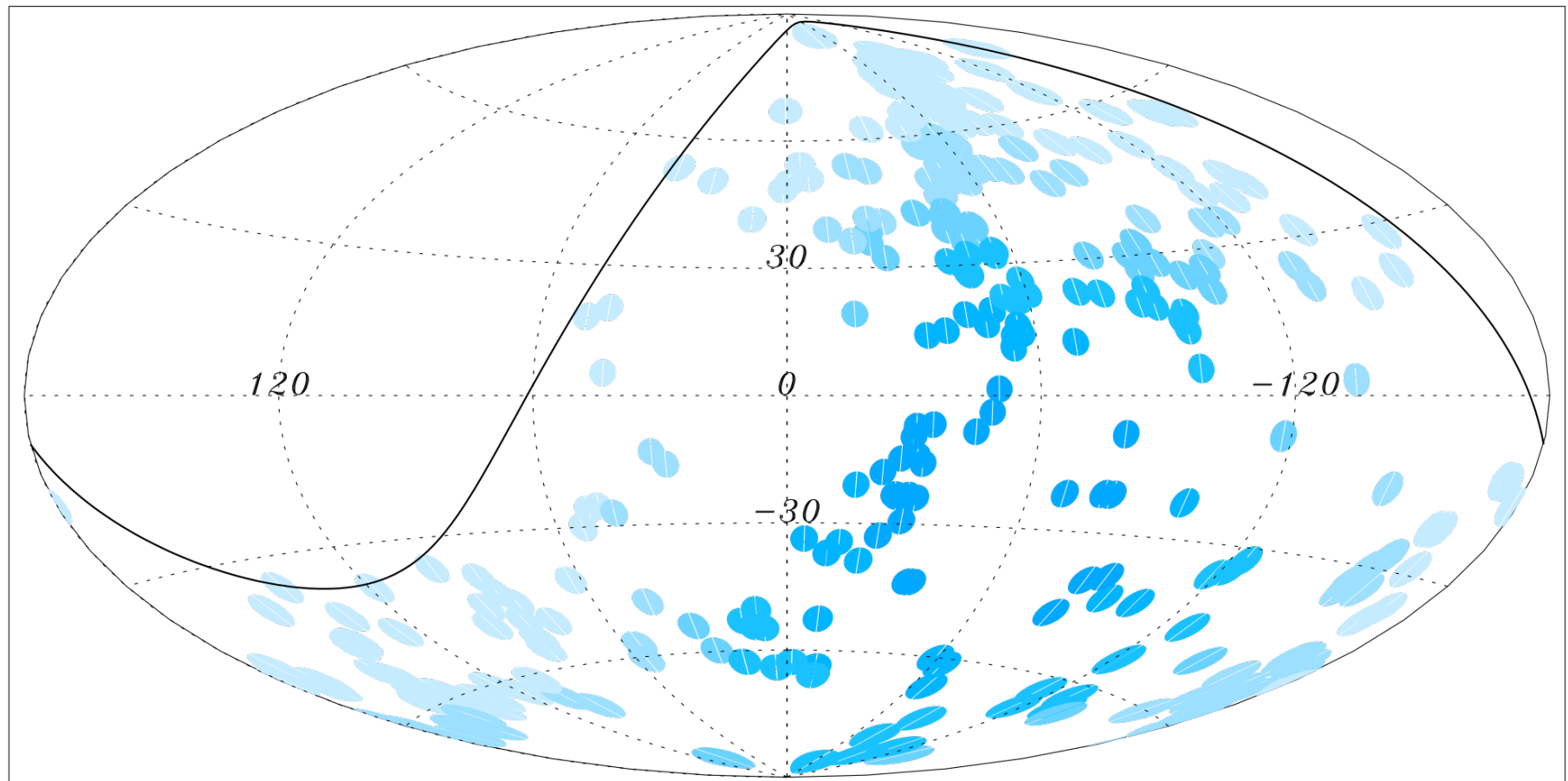
Auger VCV correlation

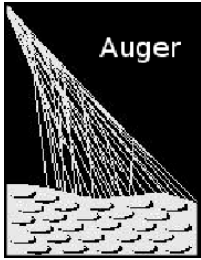
27 events test prescription: 99% isotropy rejection,
VCV catalog of AGN: $z < 0.018$, $\theta \sim 3^\circ$, $E > 57 \text{ EeV}$



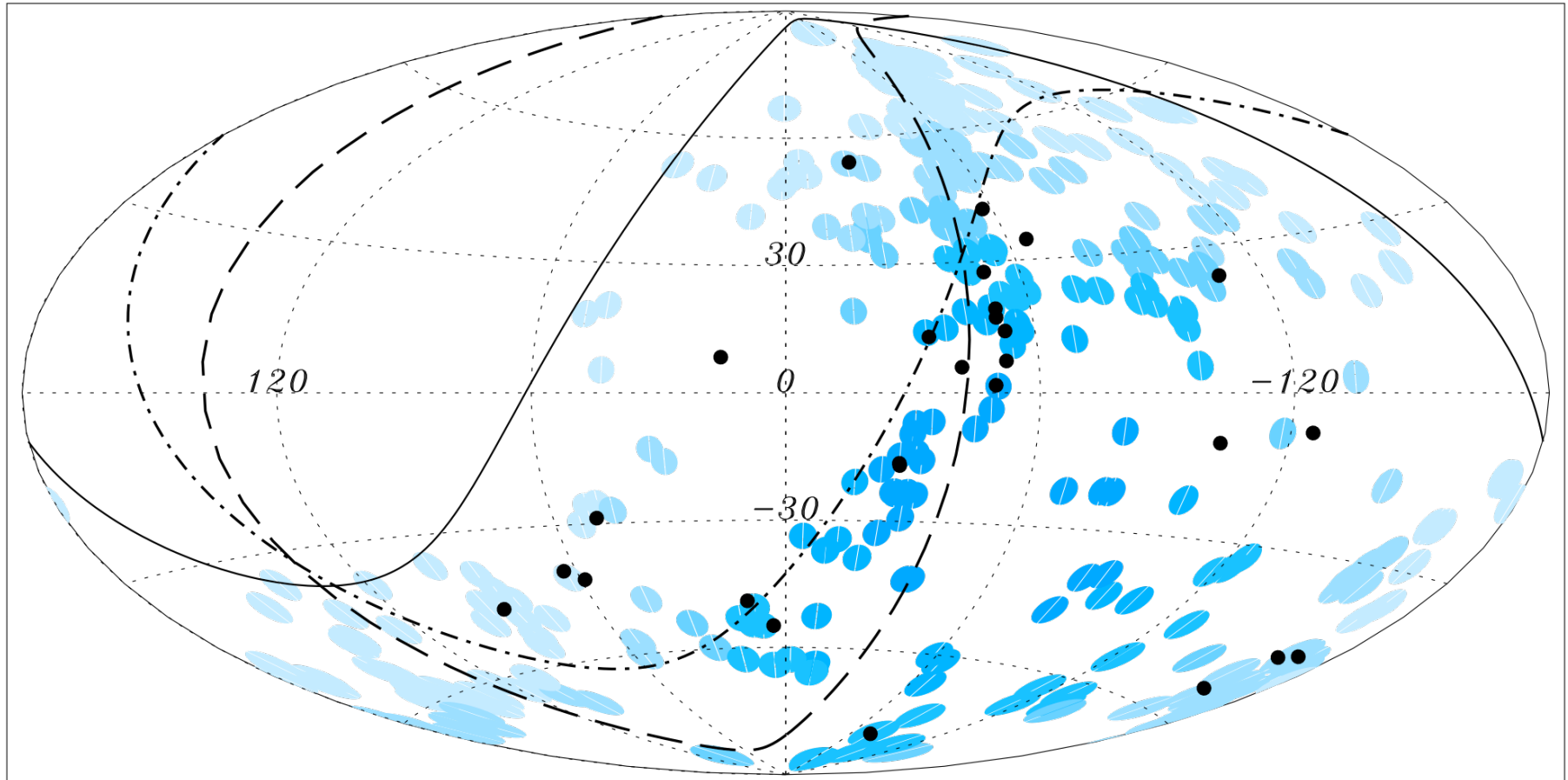


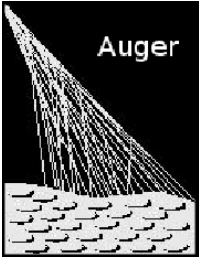
Nearby VCV AGN – 21% sky





First 27 events





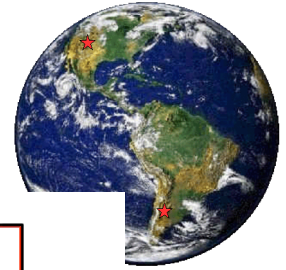
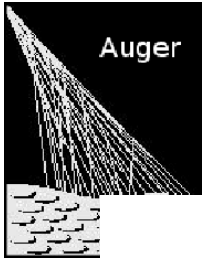
Auger South

Observed the GZK feature in the spectrum

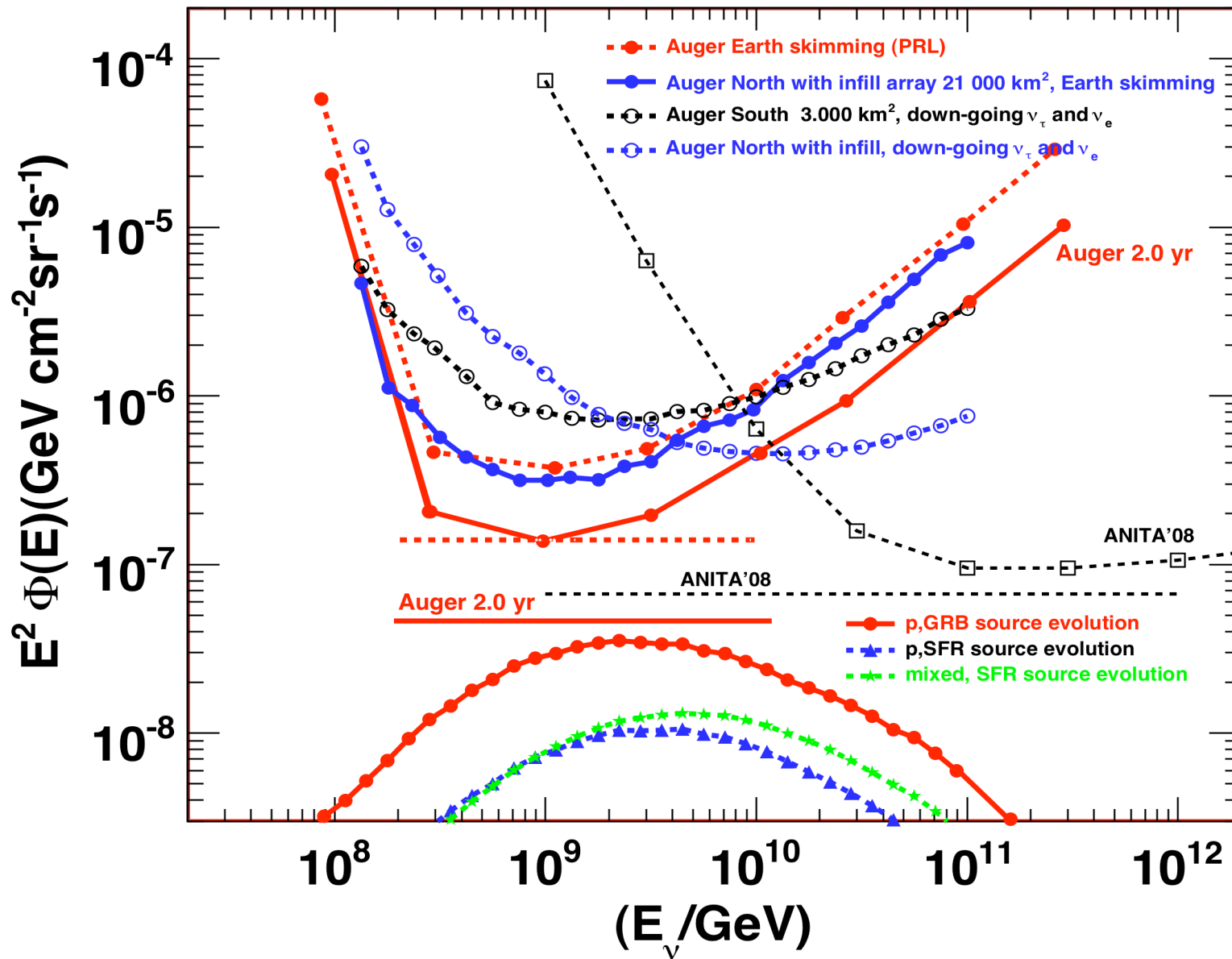
Determined Sky anisotropies > 60 EeV

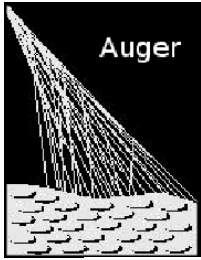
Showed that the GZK sphere is populated

Strongest UHE tau neutrino and UHE photon limits

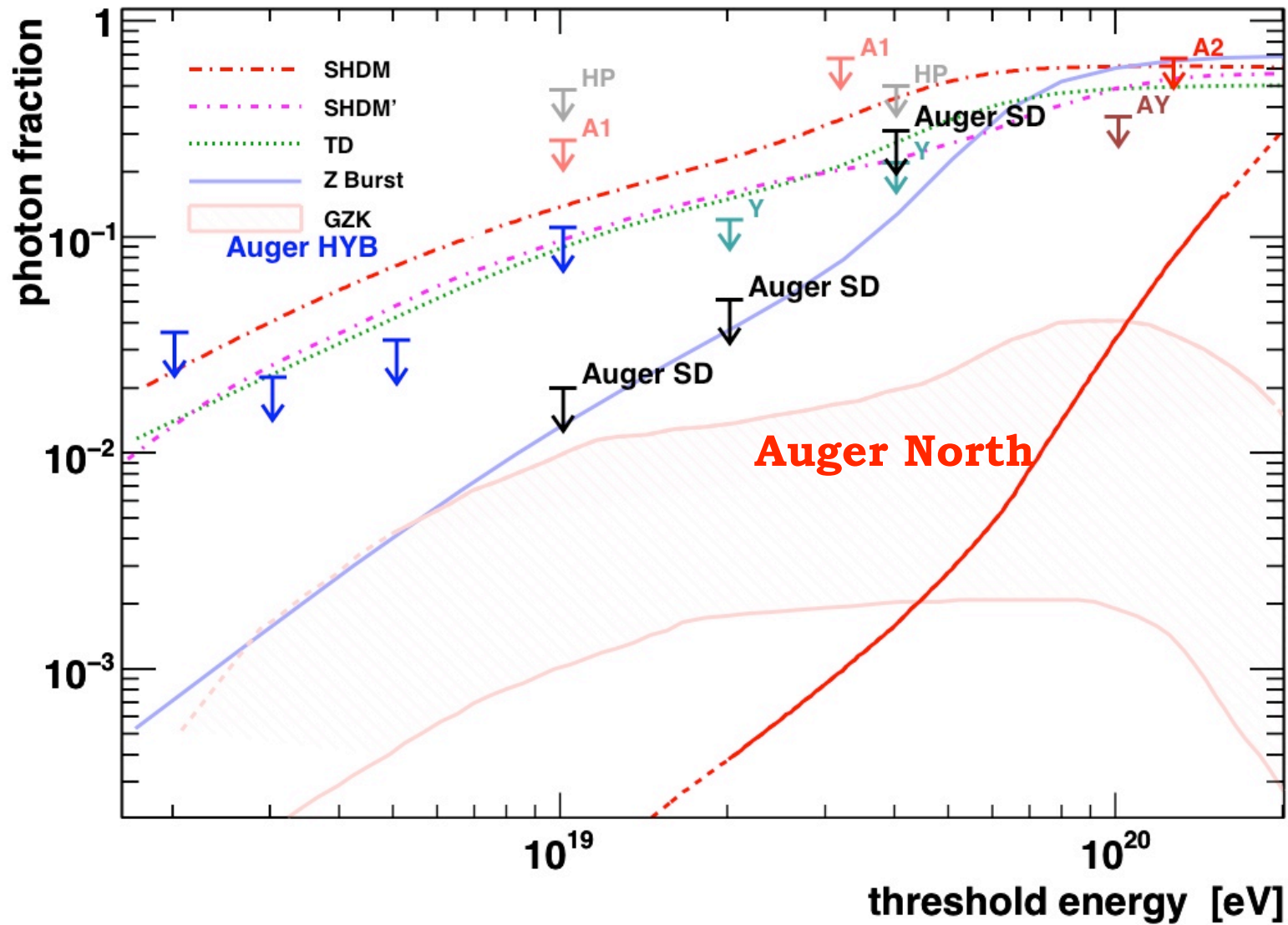


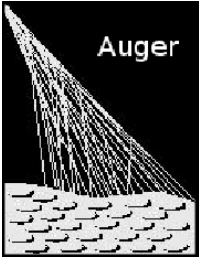
UHE neutrino limit





UHE photon limit





Auger South

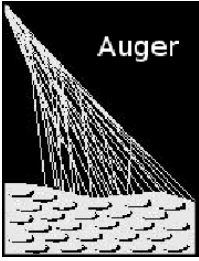
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And...!



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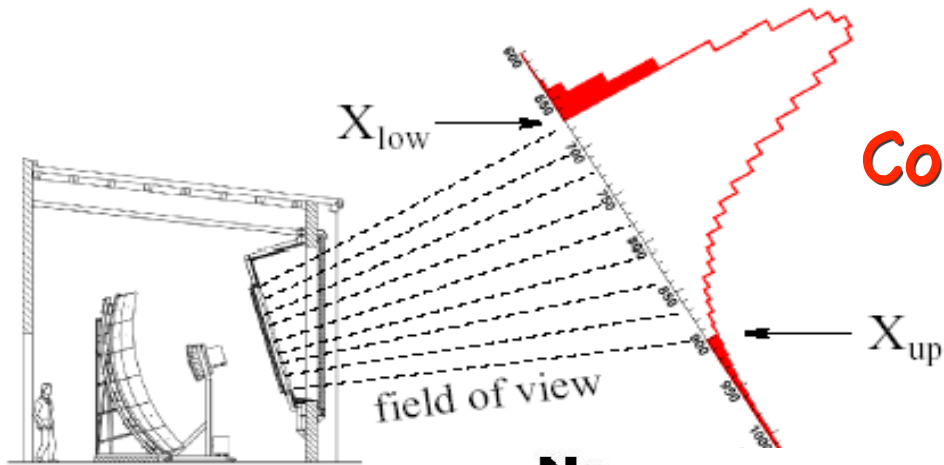
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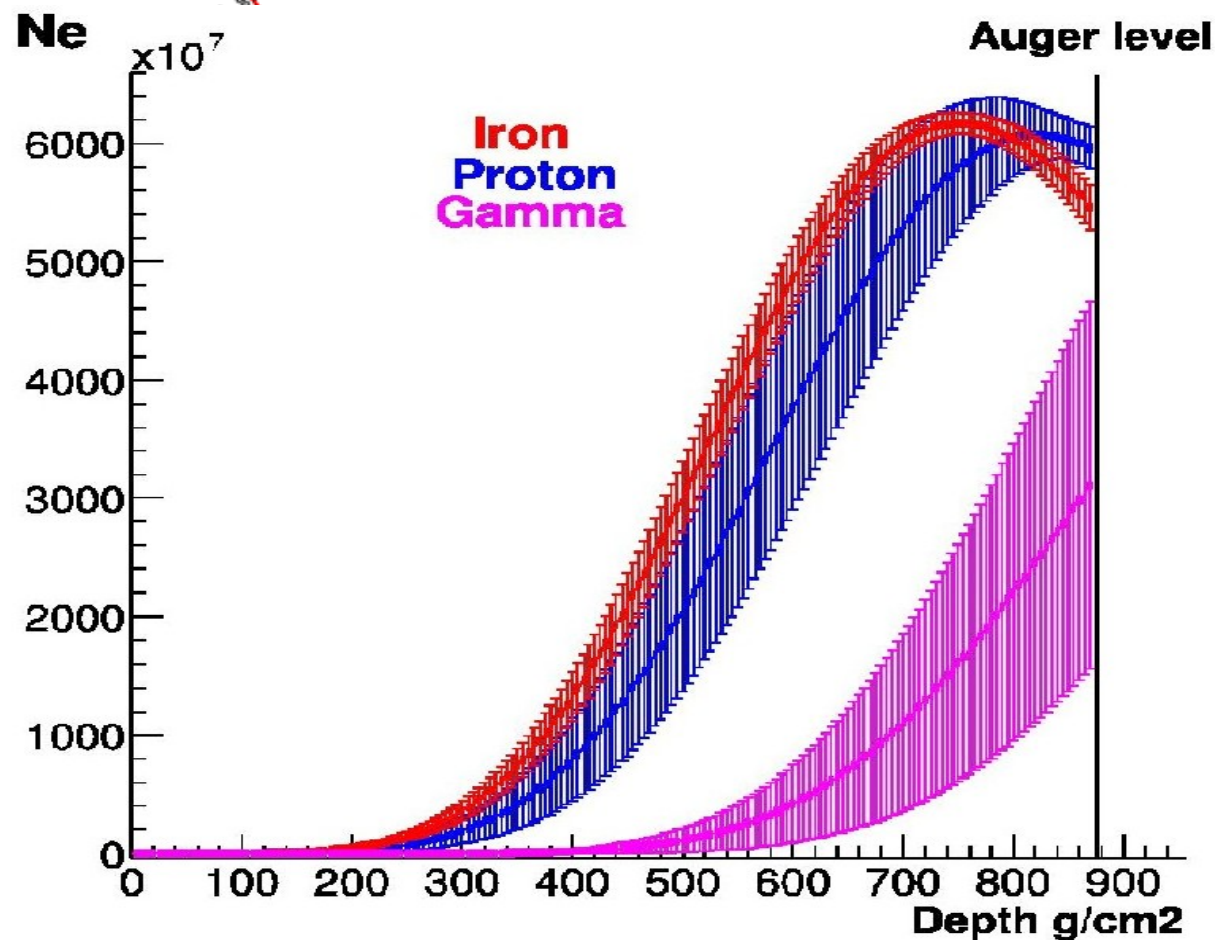
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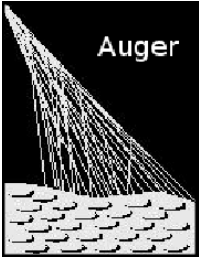
And...!

Finds a puzzling composition at the highest energies with FD statistics (< 40 EeV)



**Composition observable:
shower maximum
average & RMS**





Puzzling Composition



Unexpected Astrophysics:

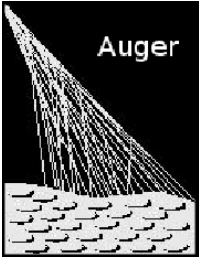
Sources are very Iron rich

and have low E_{max} (avoid proton secondaries)

Or

Interesting Particle Physics:

Hadronic Models do not represent well UHE interactions



Puzzling Composition

Unexpected Astrophysics:

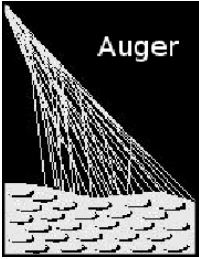
Sources are very Iron rich
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Very Bad News for Neutrino Detectors

Interesting Particle Physics:

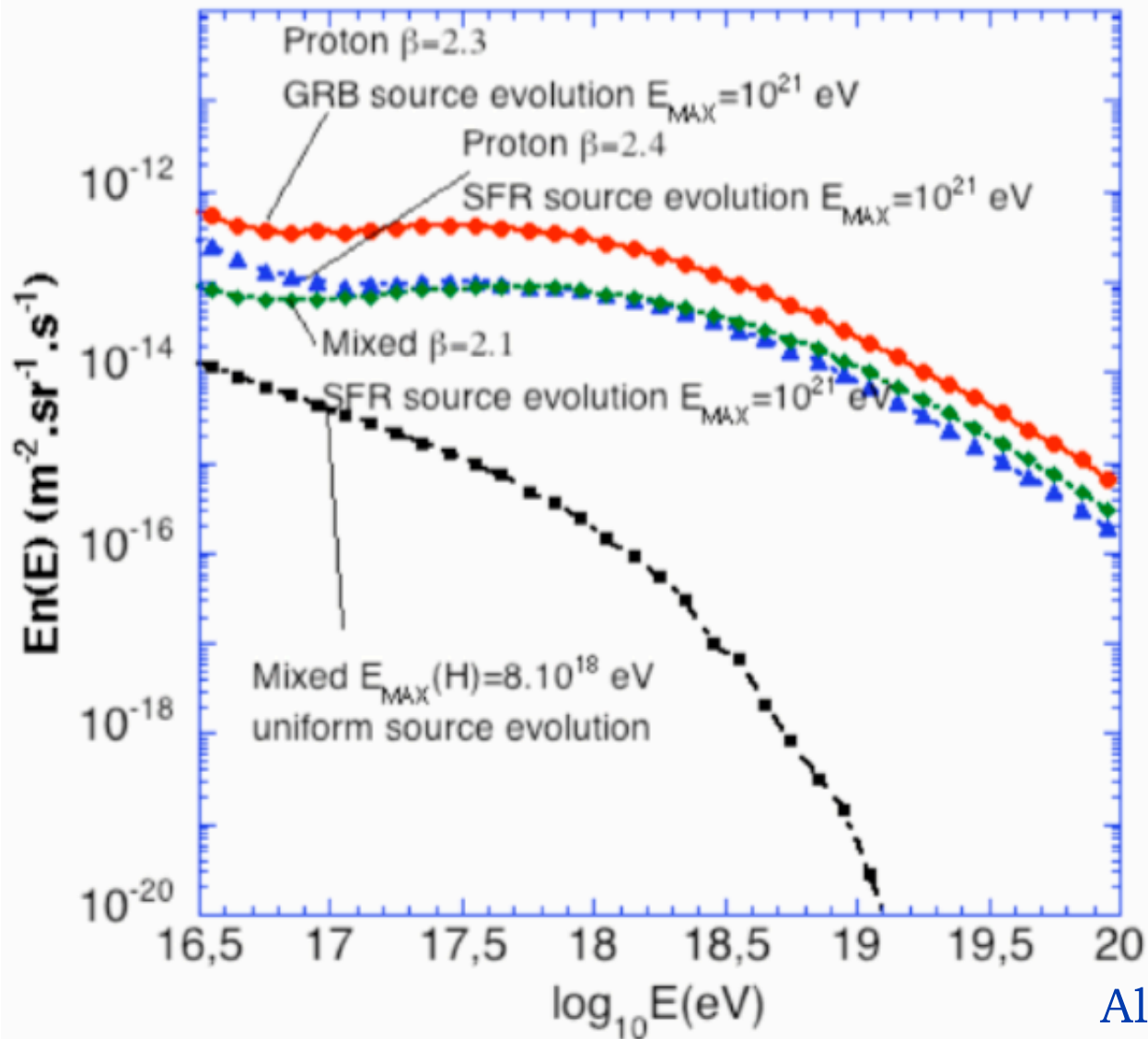
Hadronic Models do not represent well
UHE interactions

Higher Cross Sections or Multiplicities

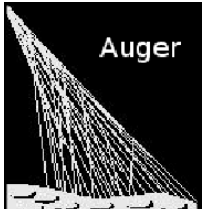


Neutrino Fluxes

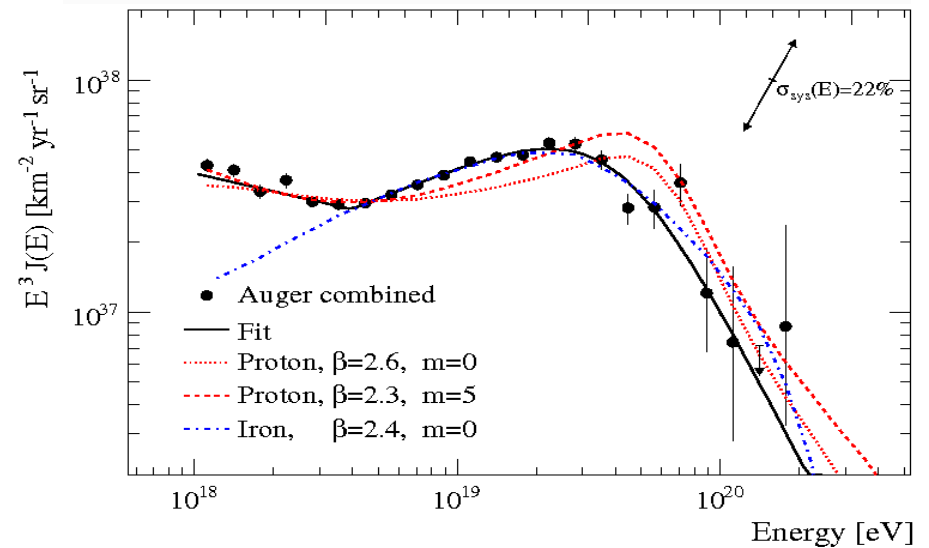
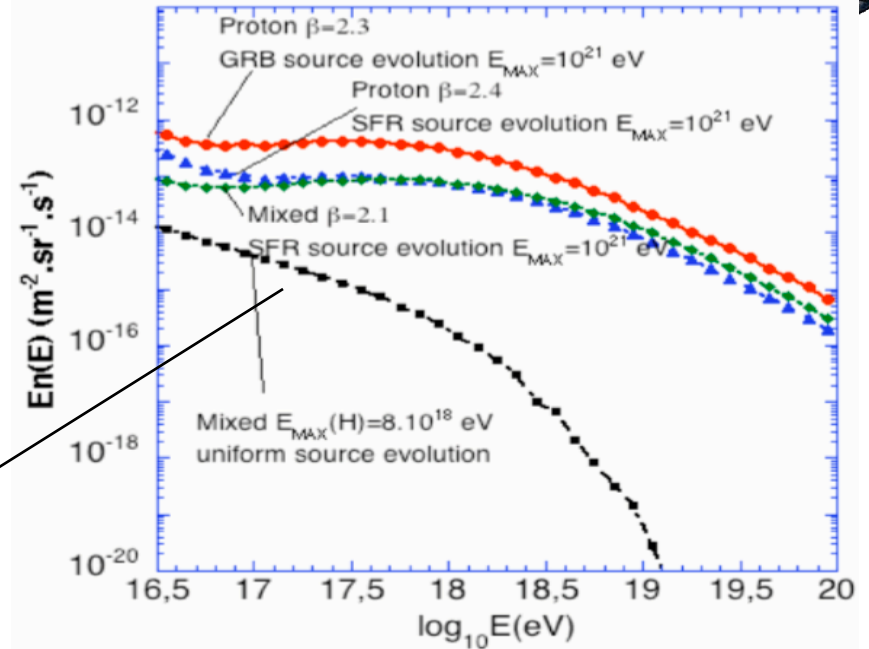
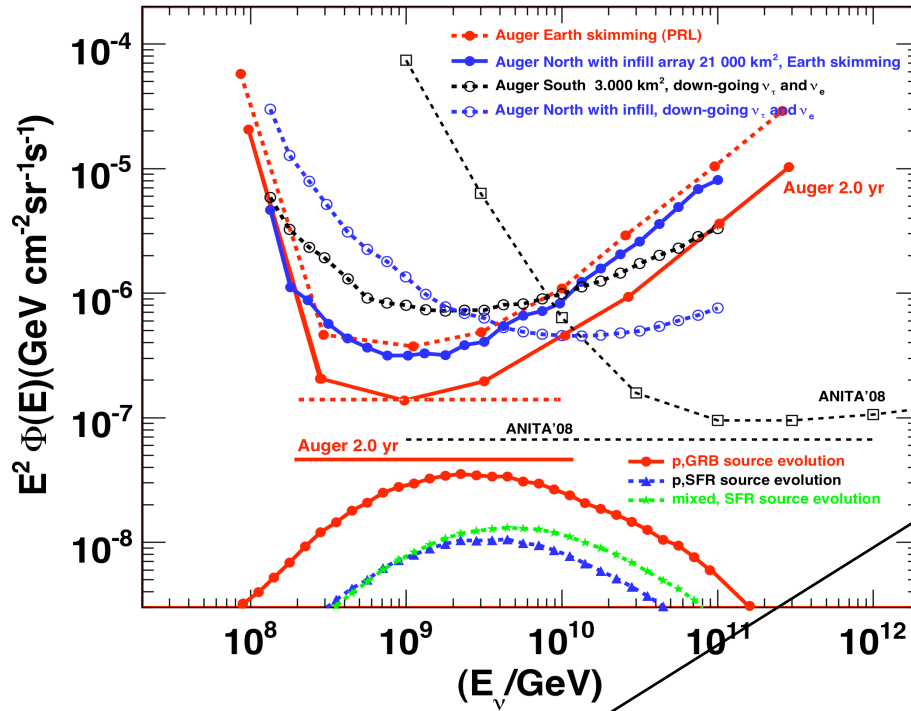
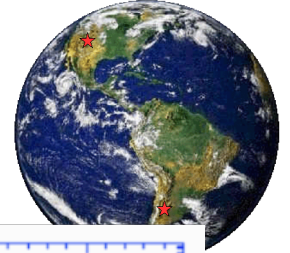
Highly Composition dependent

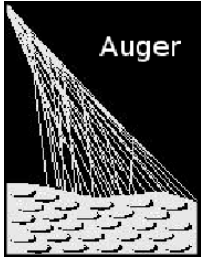


Allard et al '09



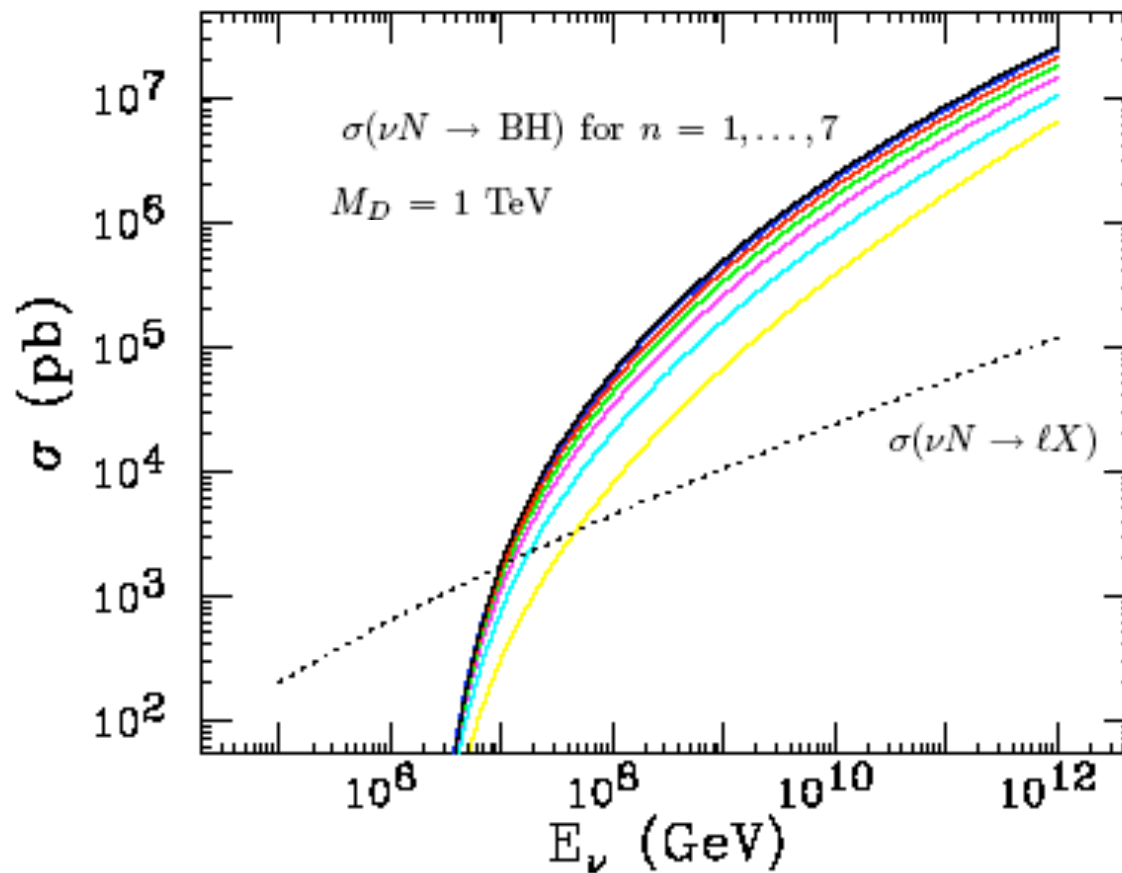
Neutrino Fluxes



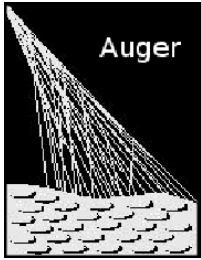


Testing Neutrino Interactions

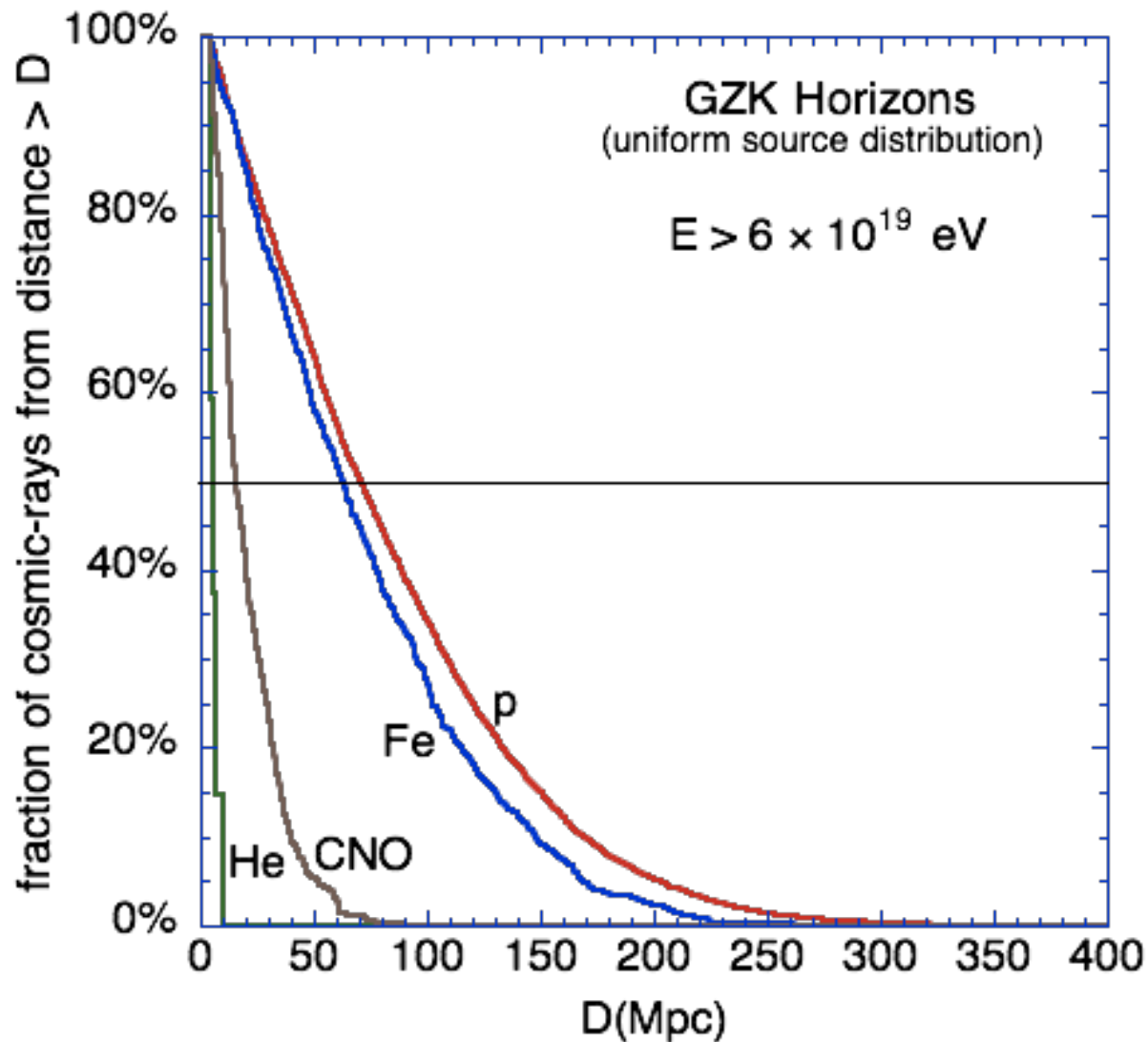
Need to know the expected GZK
neutrino flux from UHECRs

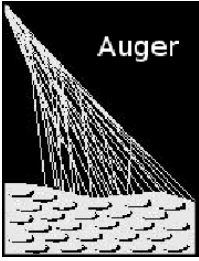


Anchordoqui et al '03



Above 60 EeV: either Protons or Iron-like

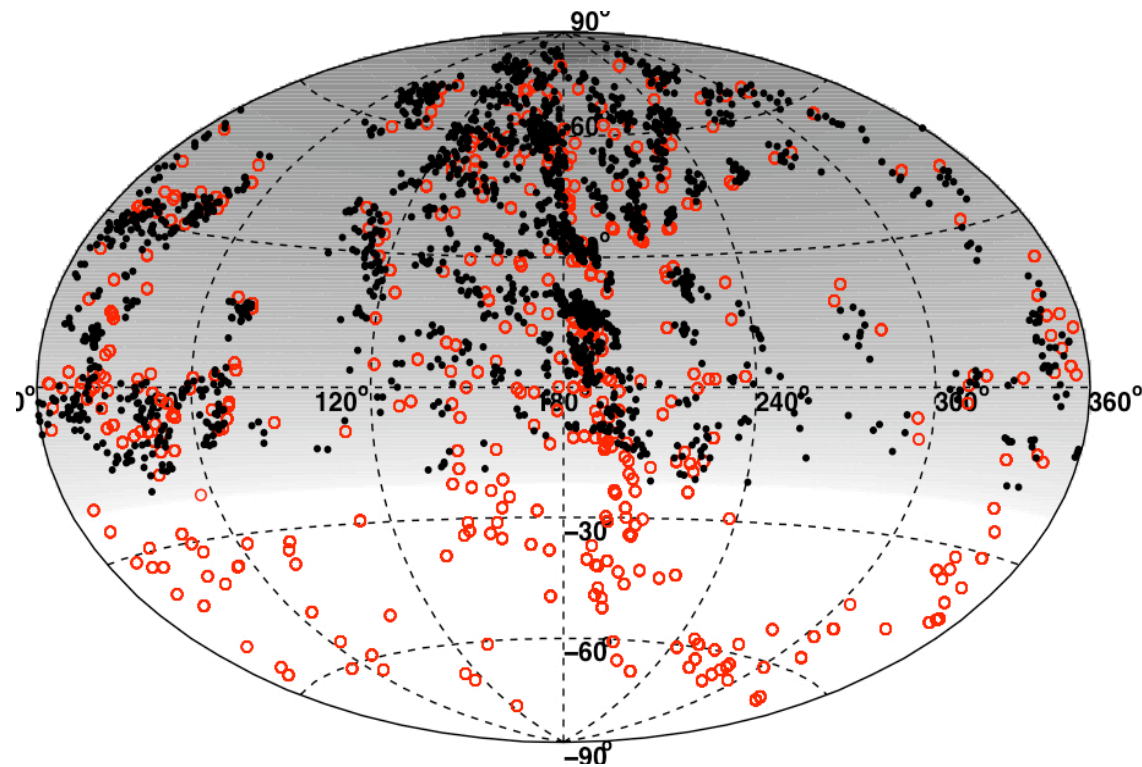


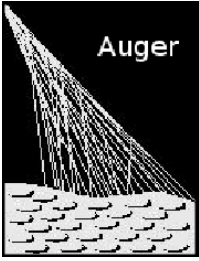


Composition >60 EeV
can be determined



Astrophysically





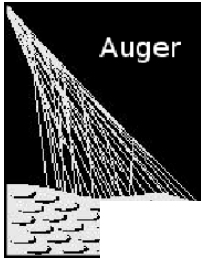
If Correlated with sources
< 10° \rightarrow protons



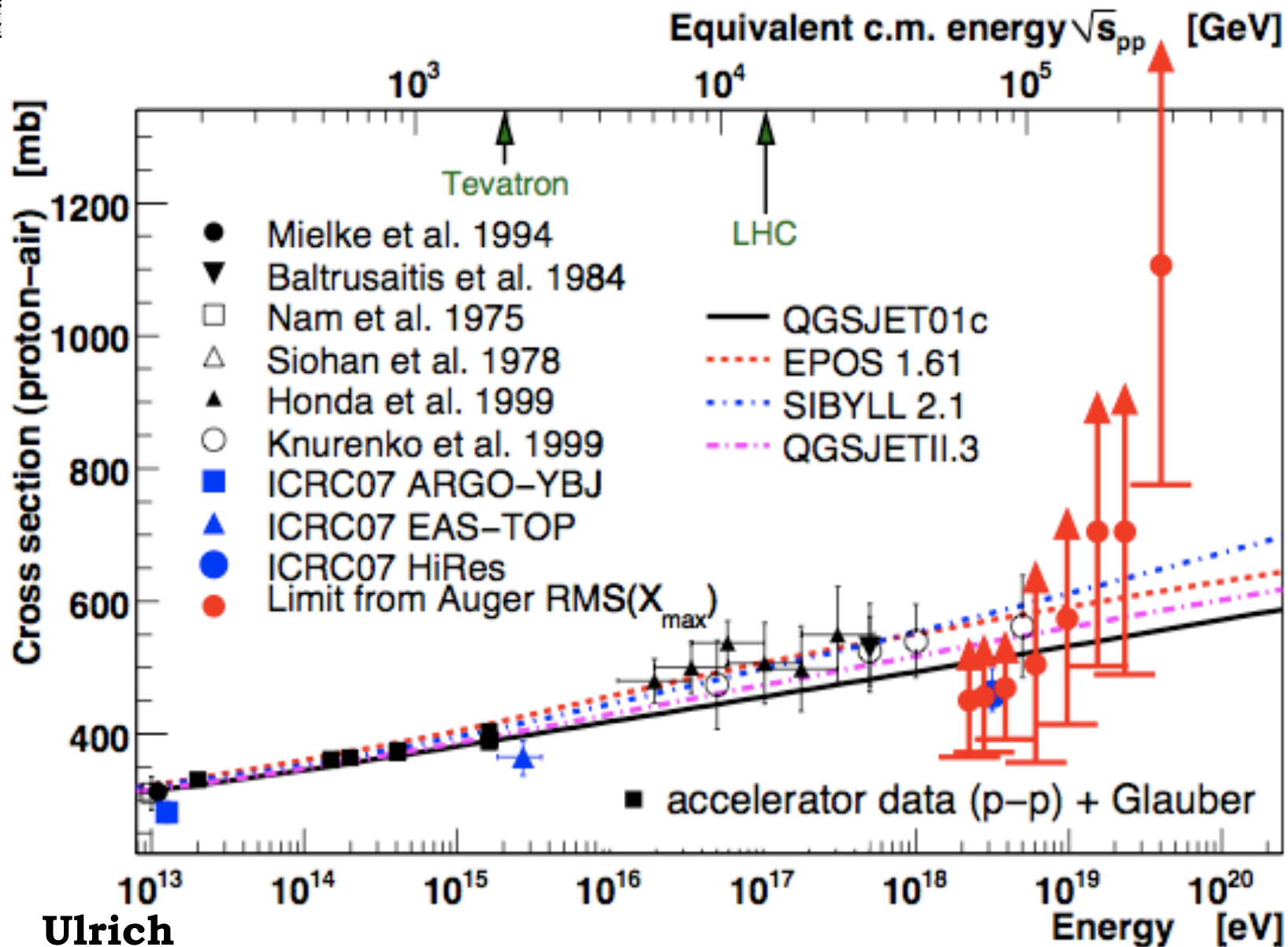
Galactic & ExtraGalactic Magnetic Fields make
iron deviate many 10° 's from source position

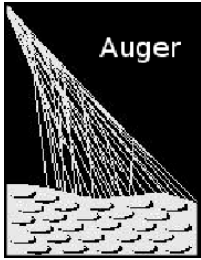
If Astrophysically shown to be protons then
hadronic models can be tested knowing the
primary composition.

For example, assume current data is protons
 \rightarrow change the cross section...

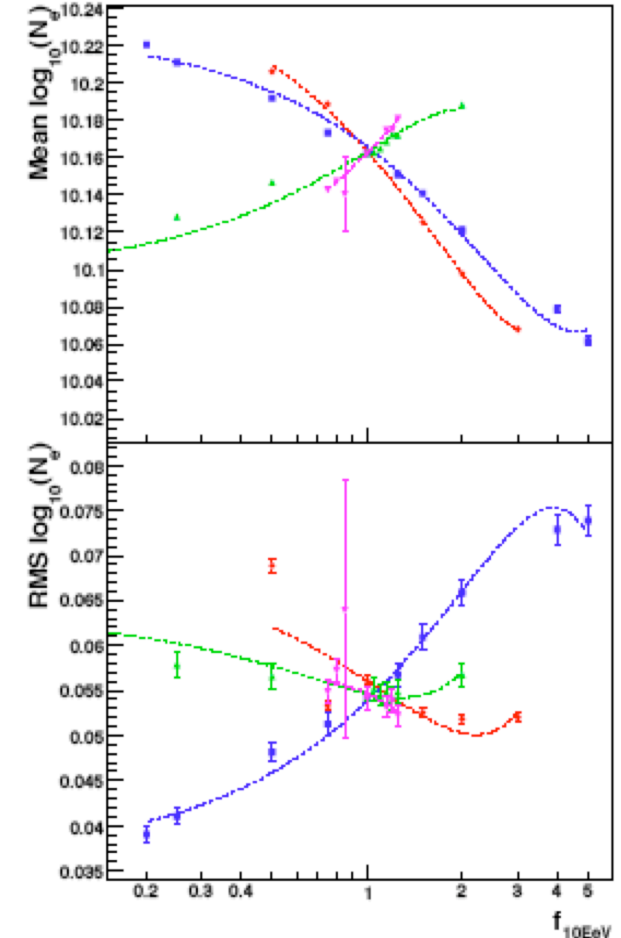
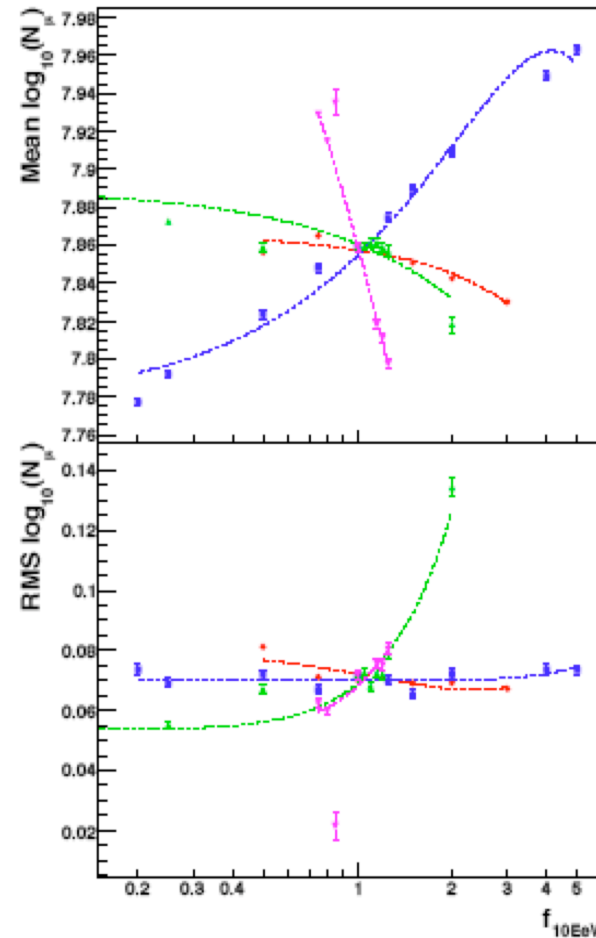
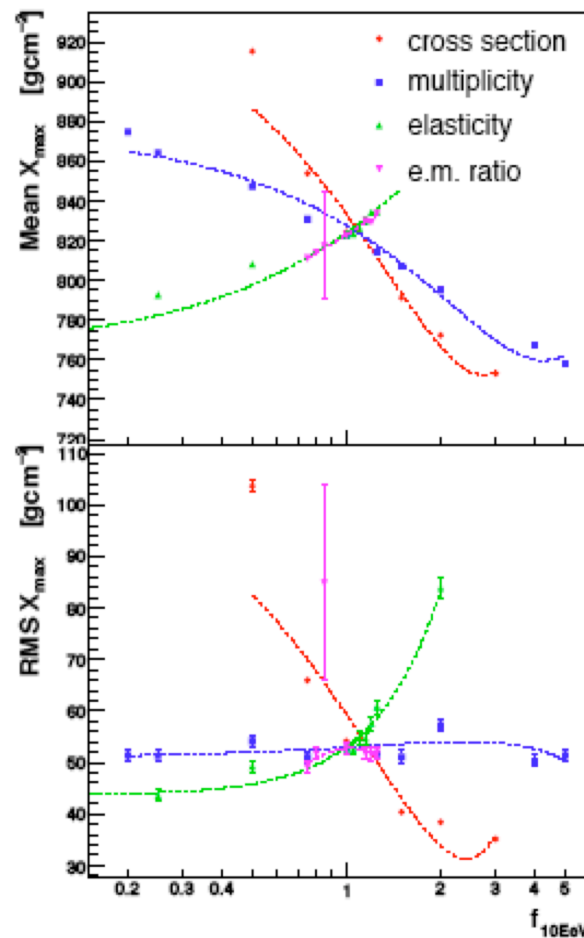


Cross Section Limits



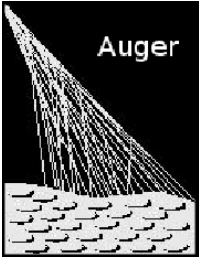


Hadronic Interactions Parameters



Scaling factor at 10^{19} eV

(Ralf Ulrich, 16-Oct-2008)



Auger South

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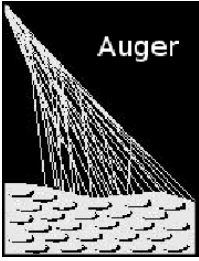
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Need to measure composition > 60 EeV



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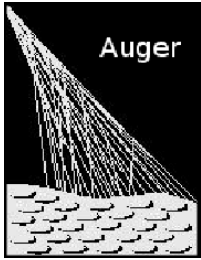
Finds a puzzling composition at around 40 EeV –

Need to measure composition > 60 EeV

PROBLEM: Not Big Enough! Can only detect

~ 25 events/yr > 60 EeV with Surface Detector

~ 2 events/yr > 60 EeV w/ Fluorescence Detector



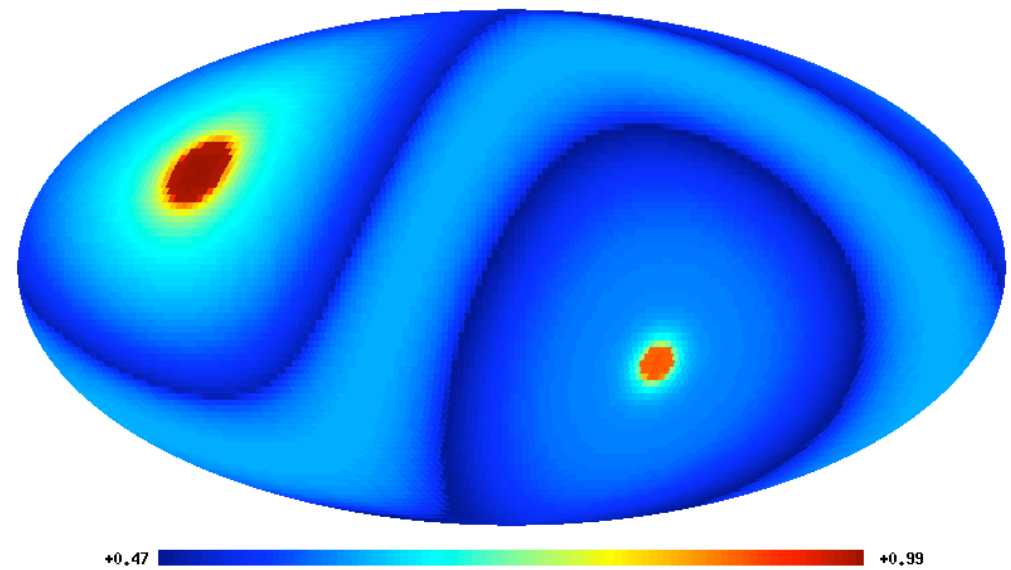
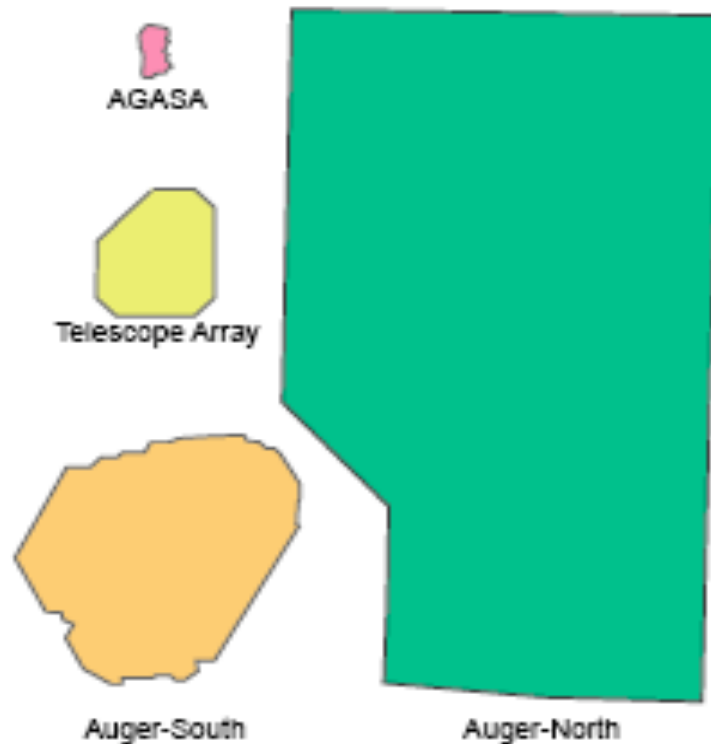
Auger North

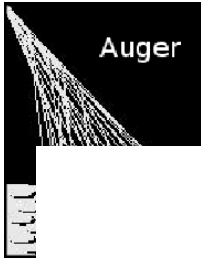
7 times bigger (for $2.3 \times \$$)

Auger North plus South will observe:

2000 events in 10 yr > 60 EeV with SD

200 events in 10 yr > 60 EeV with FD

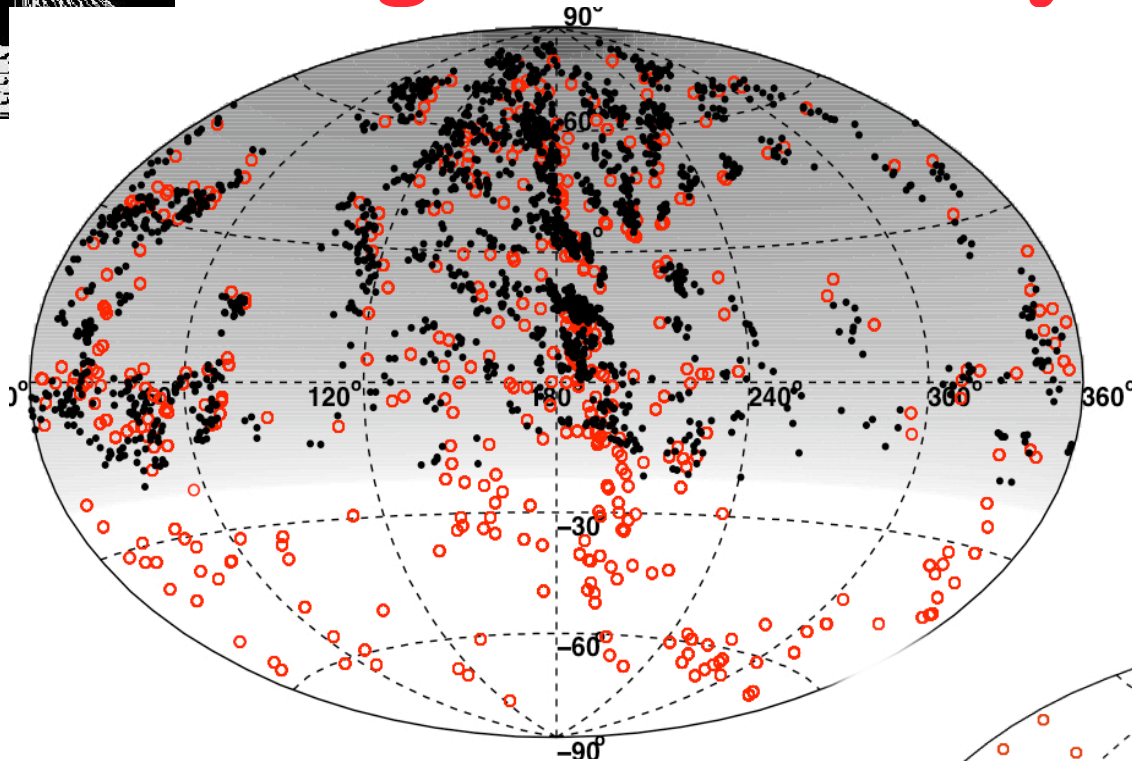




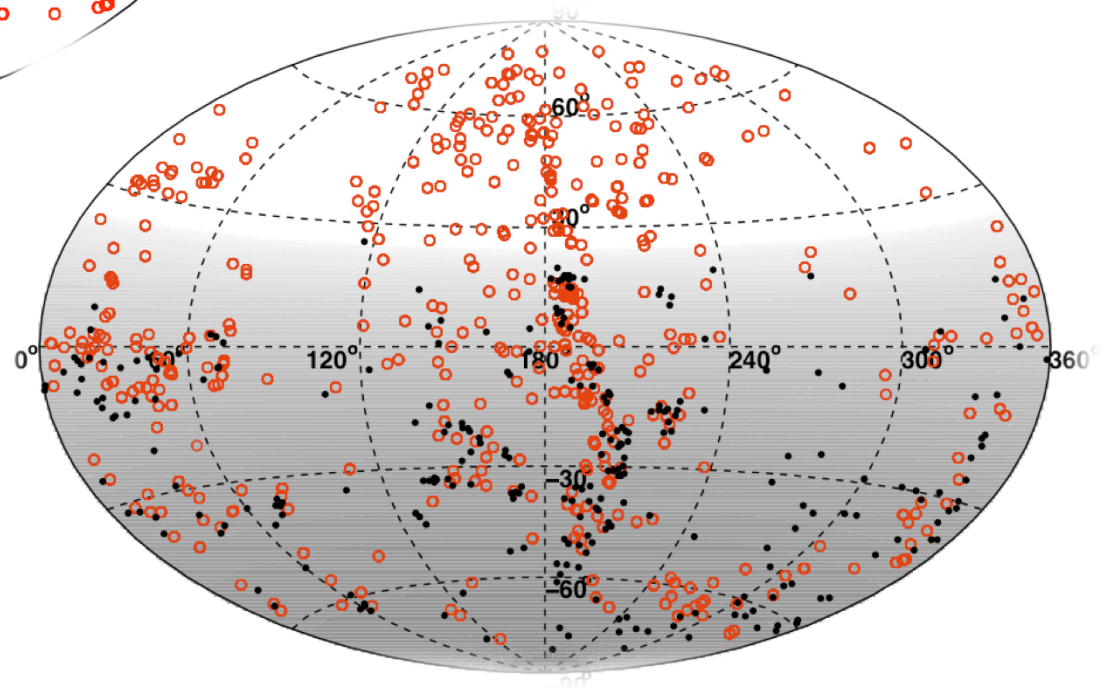
Auger North - 10 yr

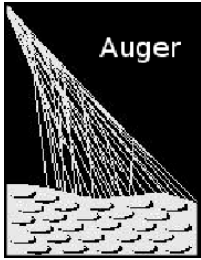


~1750 events $E > 60 \text{ EeV}$
Several events per source

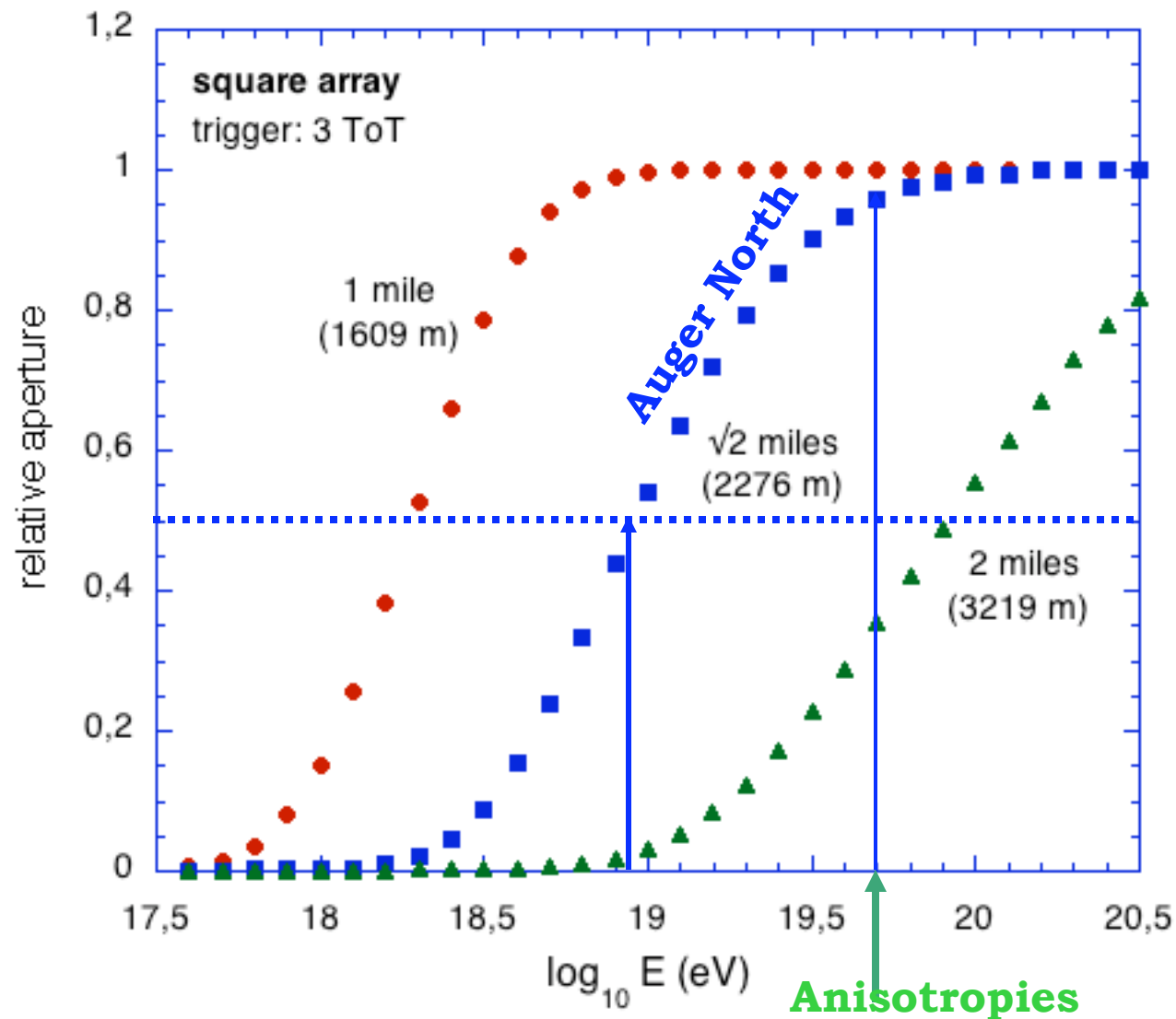


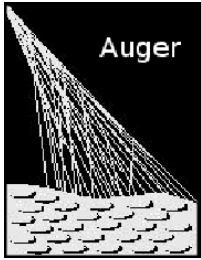
Auger South – 10 yr
~250 events $E > 60 \text{ EeV}$





Apertures & Energy Threshold

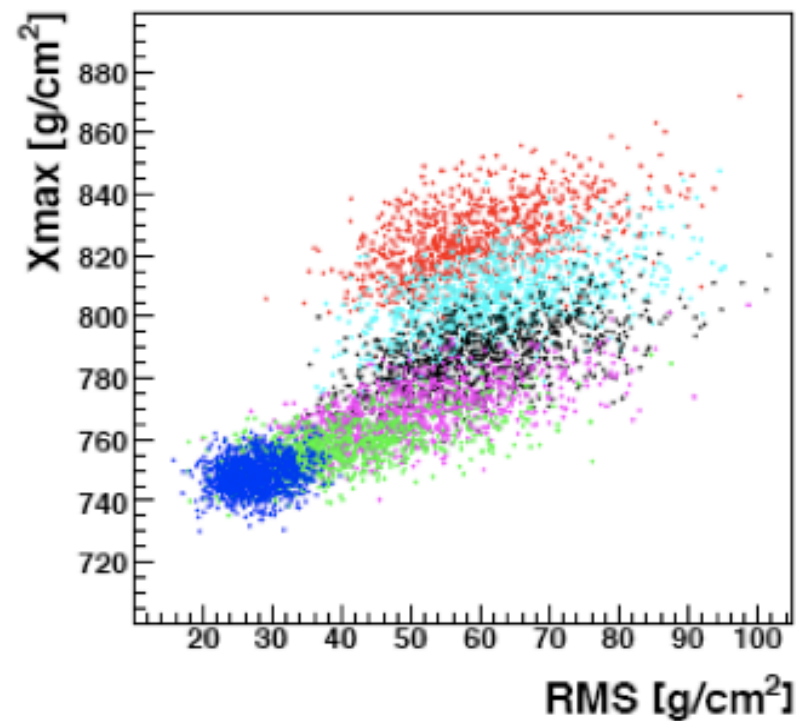
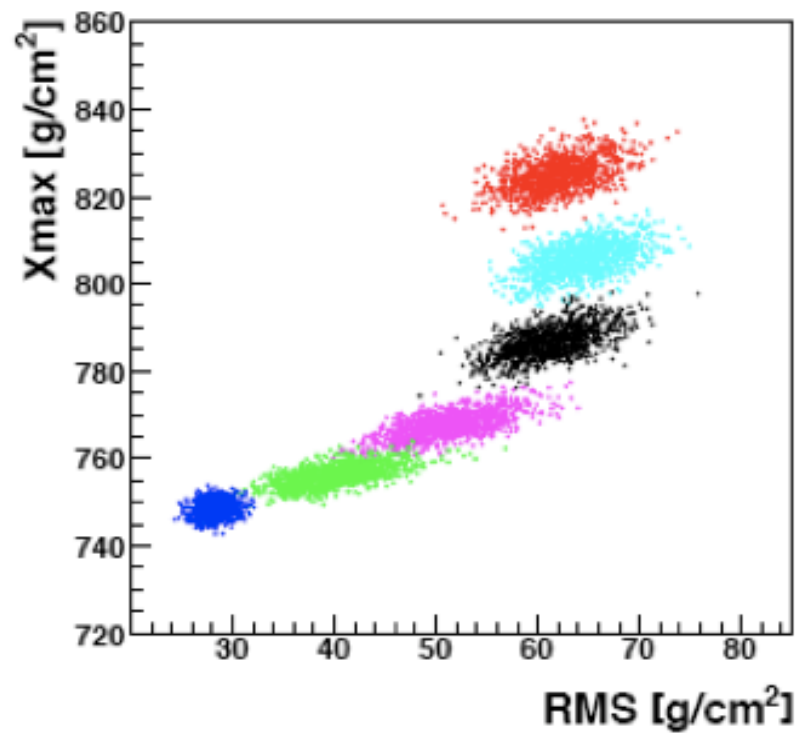




FD disentangle Composition

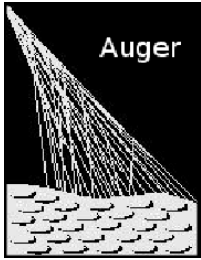
N=280

N=28

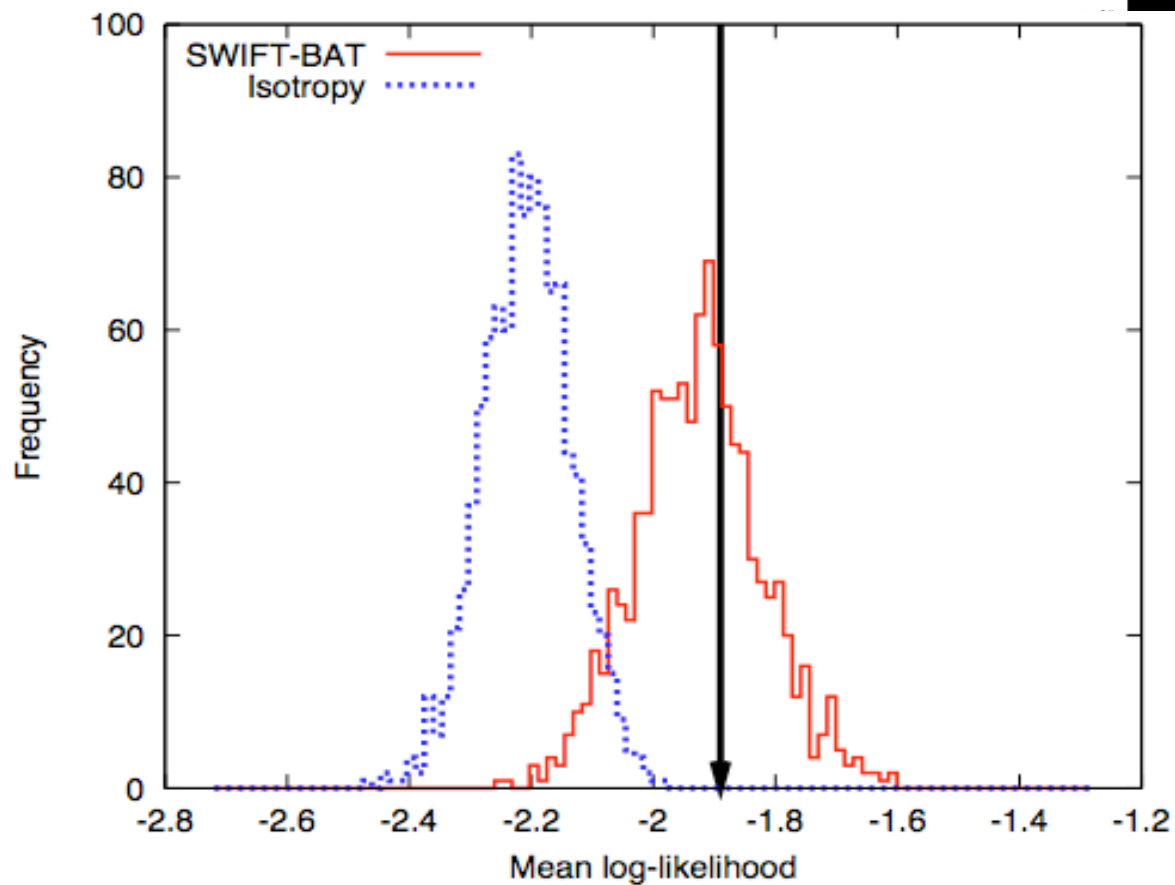


100% proton, 75% proton, 25% iron, 25% proton, 75% iron, 10% proton, 90% iron, 100% iron

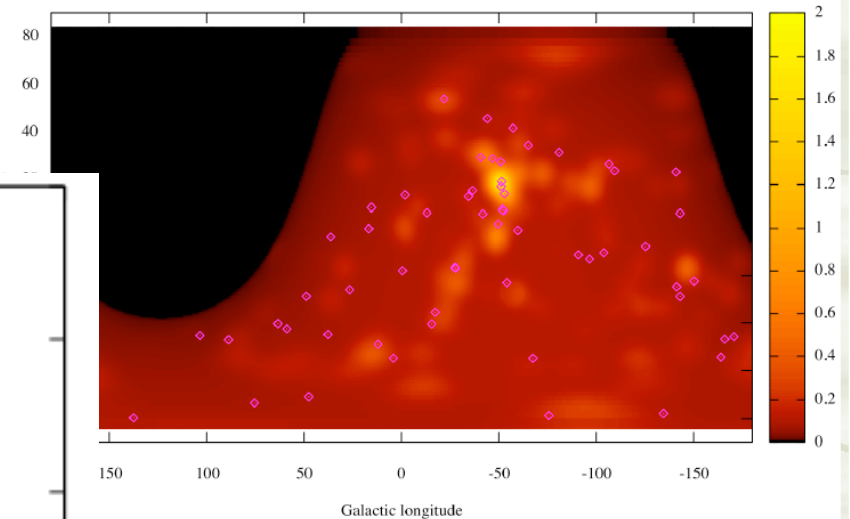
QGSJETII

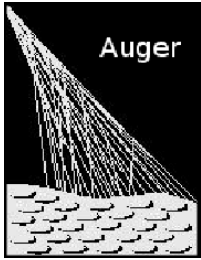


Data Prefers SWIFT-BAT AGN catalog

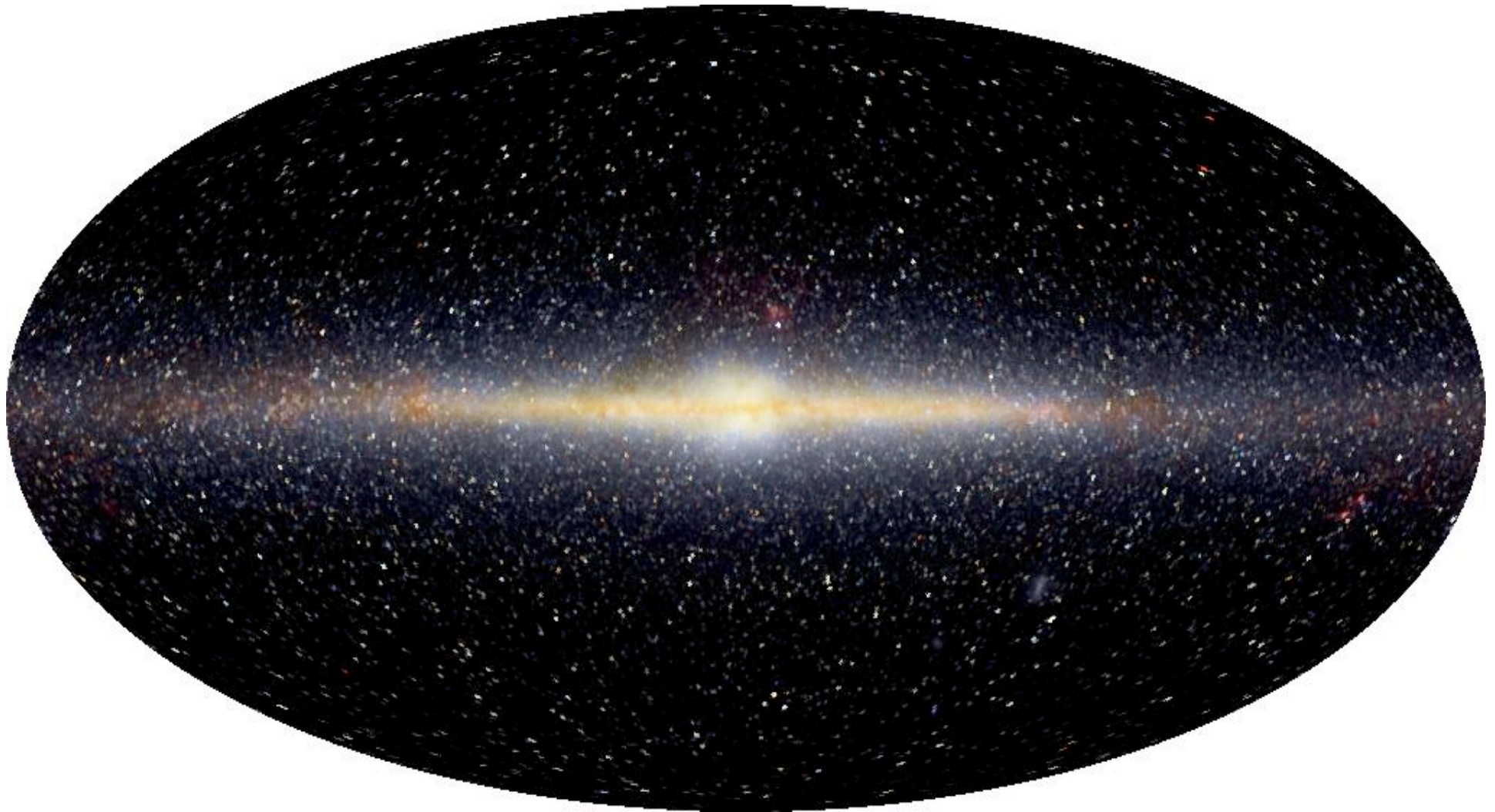


Reference Map: SWIFT-BAT (X-ray flux weighted) with smoothing angle=4 deg. + fiso=0.69, Eth=60 EeV for GZK attenuation



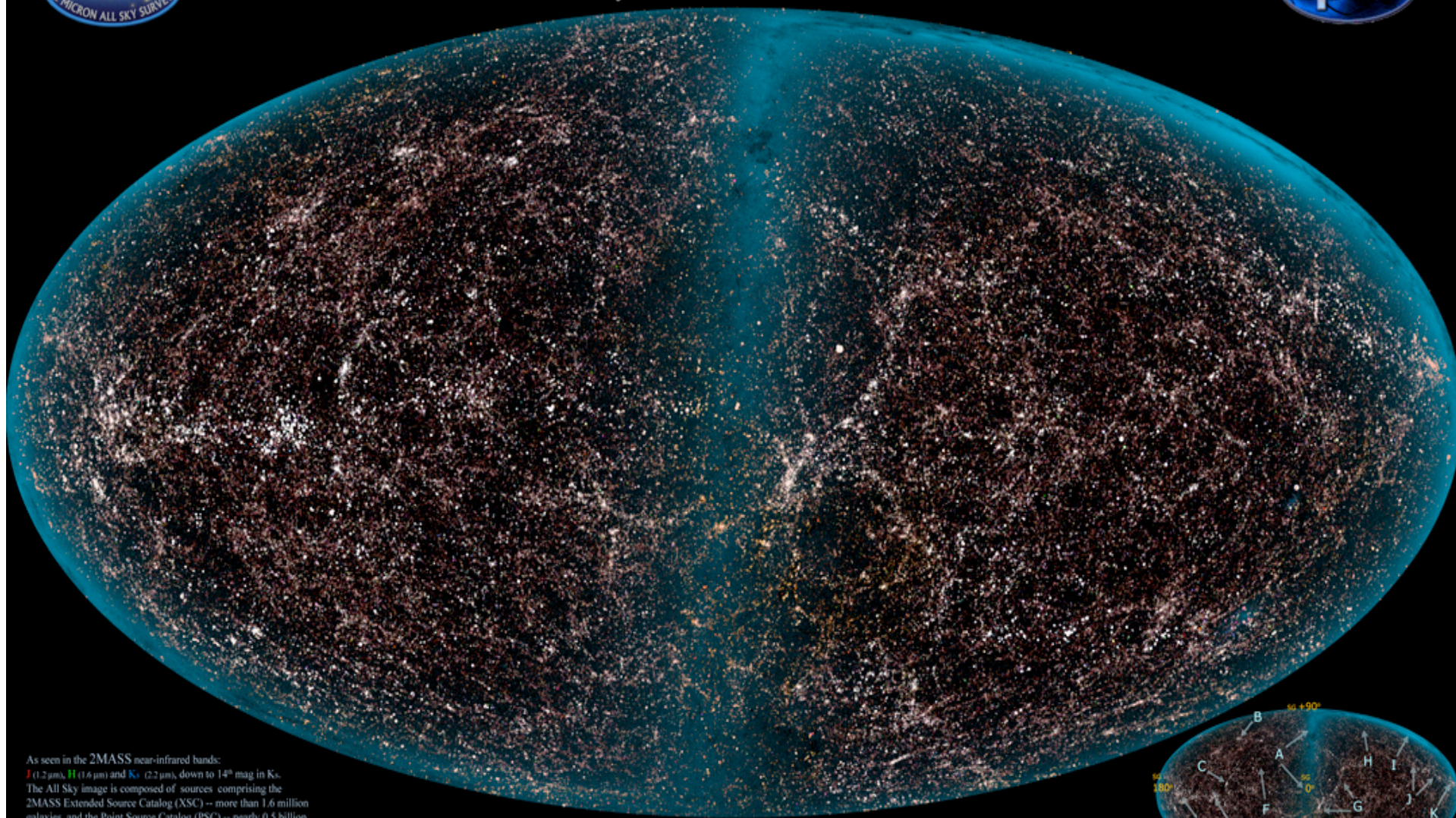


Galactic Plane

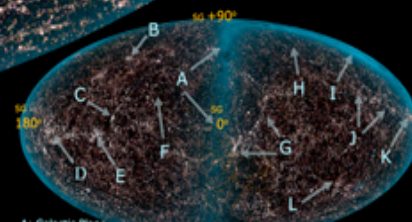




Super Galactic Plane

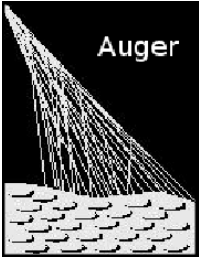


As seen in the 2MASS near-infrared bands: J (1.2 μm), K₁ (1.6 μm) and K₂ (2.2 μm), down to 14th mag in K₂. The All Sky image is composed of sources comprising the 2MASS Extended Source Catalog (XSC) -- more than 1.6 million galaxies, and the Point Source Catalog (PSC) -- nearly 0.5 billion Milky Way stars (these shown with a blue tint to contrast with the background galaxies.) The map is projected with an equal area a1loff in the SuperGalactic system (representing the plane of the Local Supercluster, including the Virgo-Coma supercluster of galaxies.) The plane of the Milky Way runs vertically across the image, with the Galactic Center to the upper right. The image was created by Drs. T.H. Jarrett, J. Carpenter & R. Hart (IPAC/Caltech).



- A: Galactic Plane
- B: Hercules Supercluster
- C: Coma Cluster
- D: Shapley Concentration/Hydra-Centaurus Supercluster
- E: Virgo Cluster/Local Supercluster
- F: Bootes Void
- G: Perseus-Andromeda Supercluster
- H: "Local Void"
- I: Galactic Center
- J: Pisces-Indus Supercluster
- K: "Great Attractor"/Abell 3627
- L: Horologium Supercluster





Determine Source Distribution

Type of Sources – acceleration models

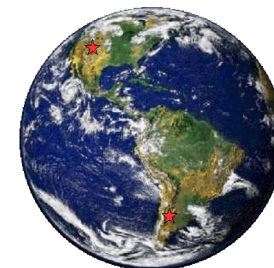
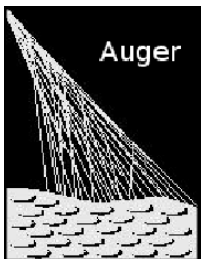
Brightest Source Spectrum – acc. models

Test shower properties of primaries

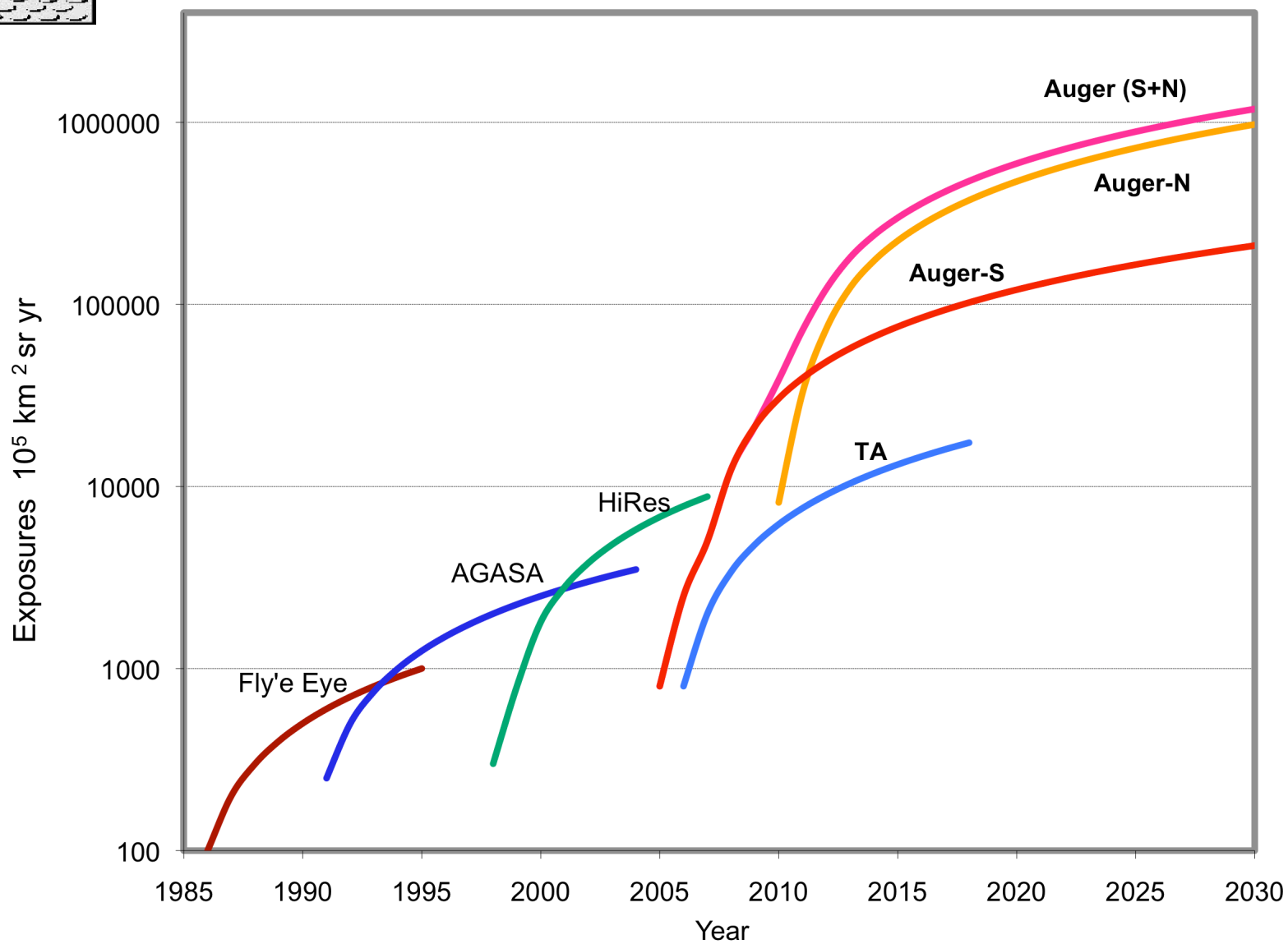
> 100 TeV (>335 TeV): Protons? Iron?

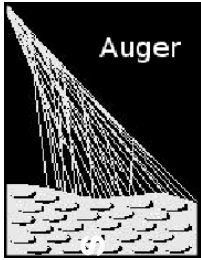
Predict Cosmogenic (GZK) HE Neutrino &
Photon Flux – test interactions > 1 TeV

Constrain Cosmic Magnetic Fields

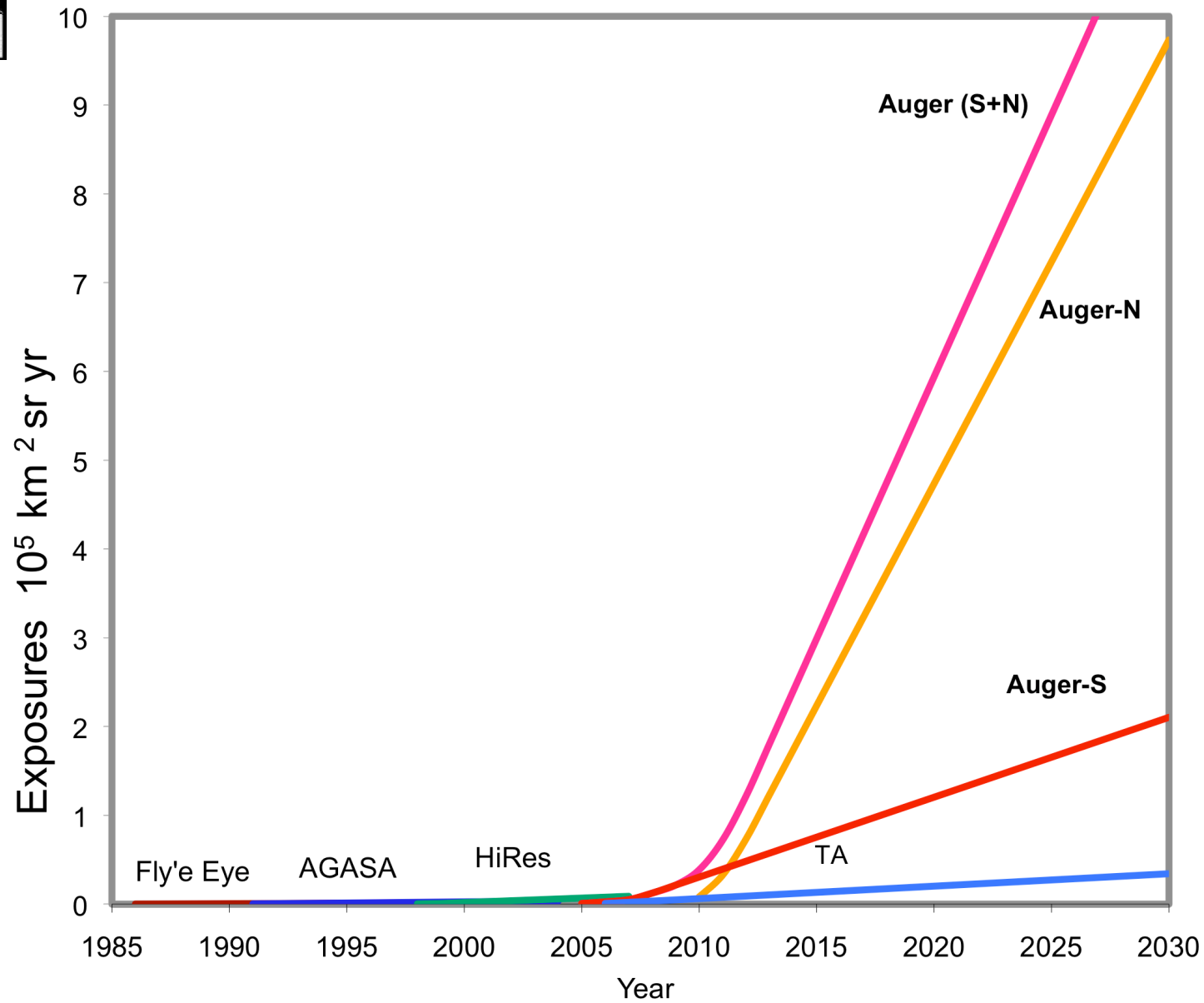


Exposure Evolution





Exposure Evolution – Linear

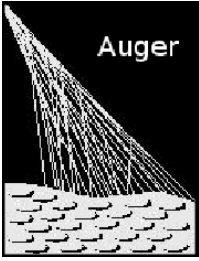


The background of the slide is a composite image. The upper portion shows a deep space scene with a bright, glowing galaxy or nebula against a dark, star-filled sky. A series of thin, purple lines radiate from the top left, representing a cosmic particle shower. The lower portion of the image transitions into a view of Earth's surface, showing blue oceans and white, swirling clouds.

The Pierre Auger Observatory

Auger North

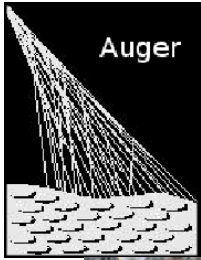
- Science of Auger North
- Features of Auger North
- Auger North R&D
- Organization and Management
- Cost, Funding and Schedule
- Fermilab and Auger North



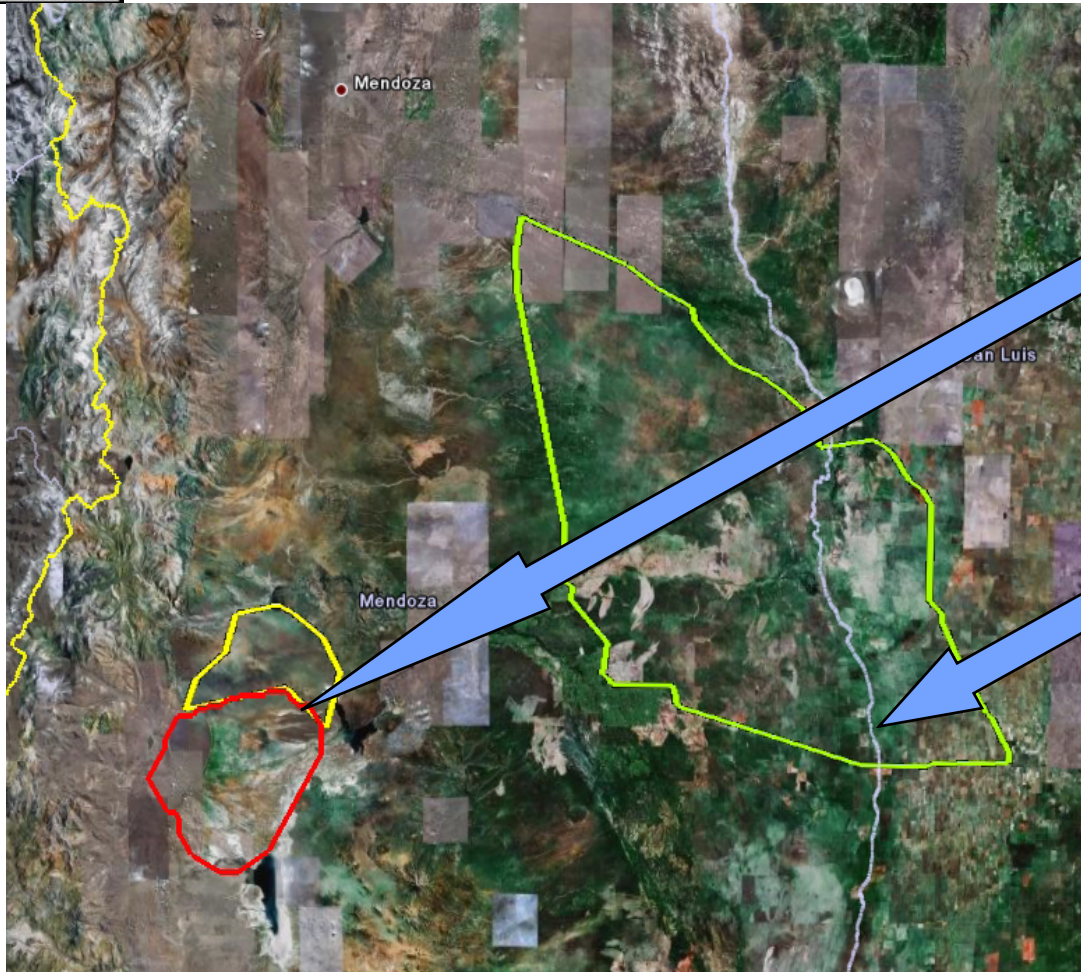
Auger North Objectives

Obtain the greatly expanded data set needed to solve the puzzles of the sources and primary composition.

Extend coverage to the northern sky.



Larger Aperture for the Auger Observatory *Possibilities*



Auger South

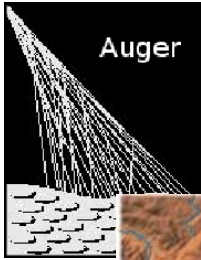
3000 km² at the
current site could
be expanded to
5000 km².

20,000 km² in a
remote area

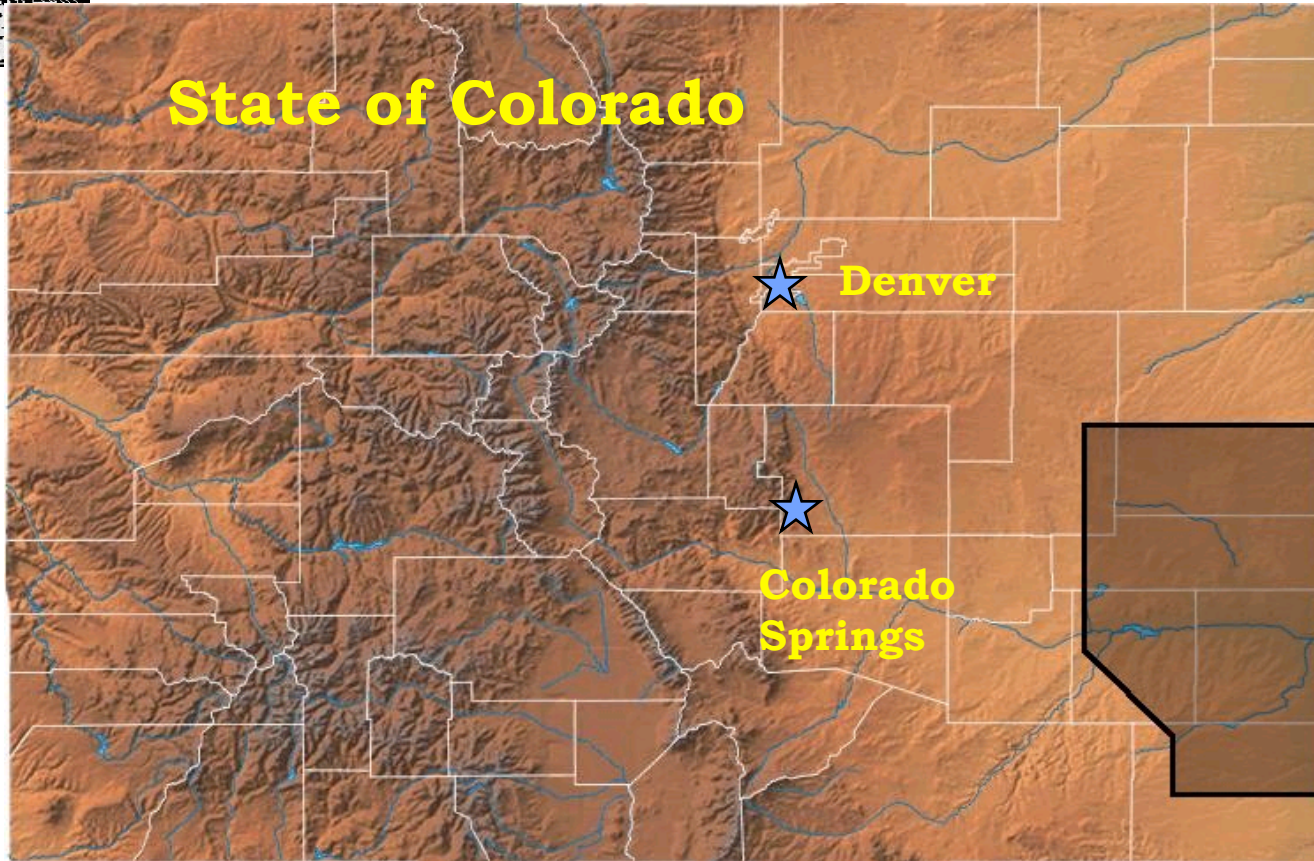
Auger North

20,000 + km² in SW
Colorado

Full Sky coverage



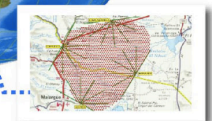
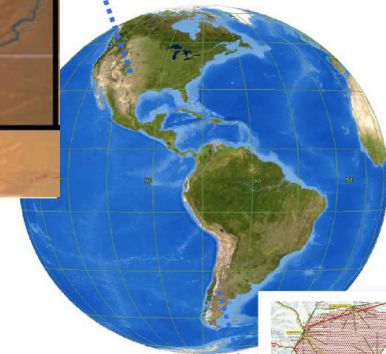
Features of Auger North



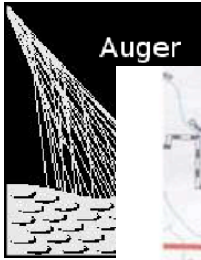
**Auger
North**

**Auger North:
4000 detectors
1.42 mi Square Grid
21,000 km² (8000 mi²)**

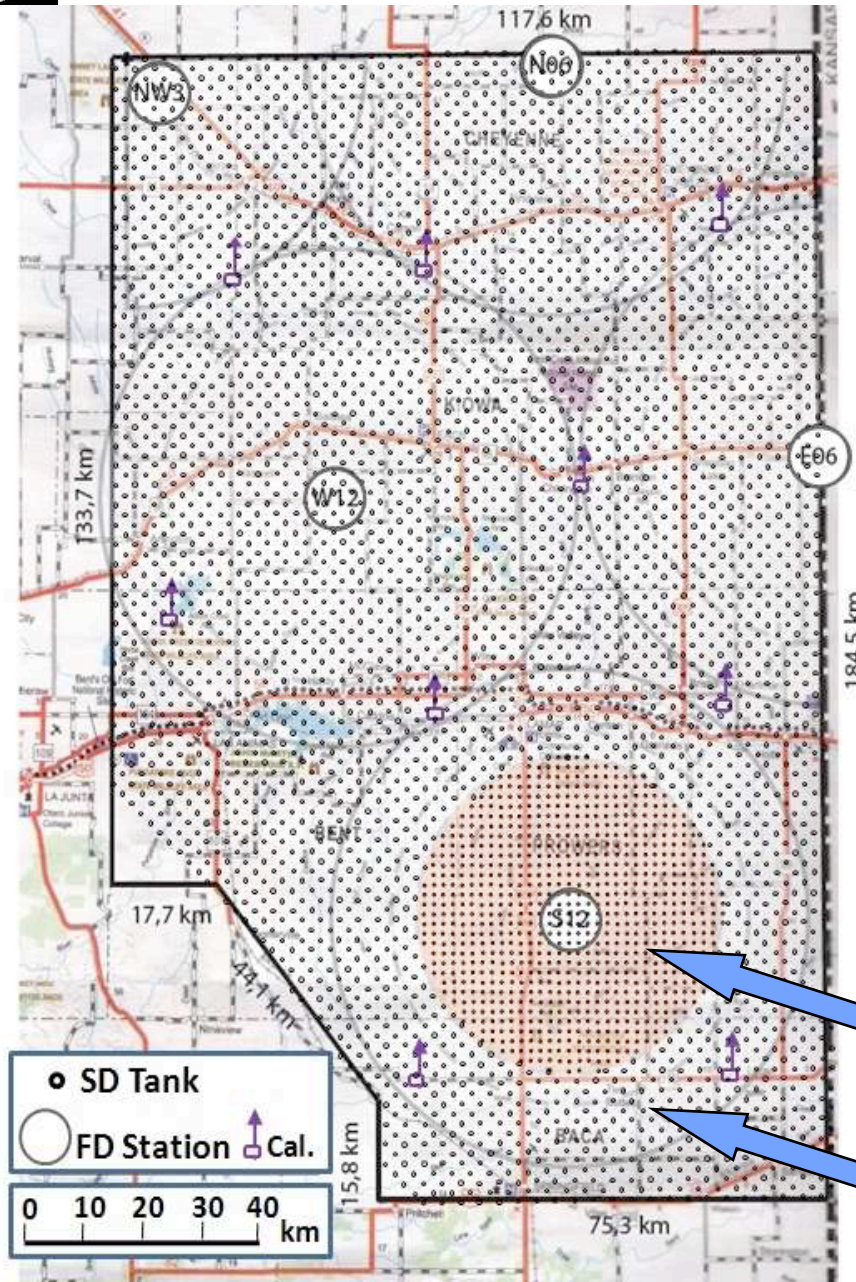
**Auger South:
1600 detectors
1.5 km Triangular Grid
3000 km² (1200 mi²)**



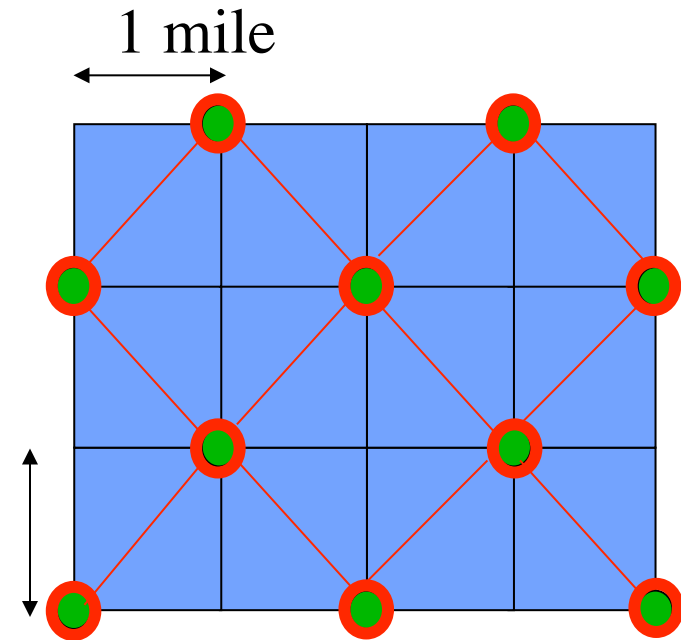
**Auger South
to scale**



Features of Auger North

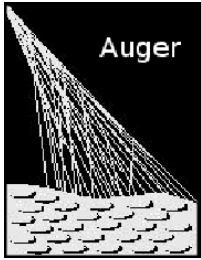


Detector Layout

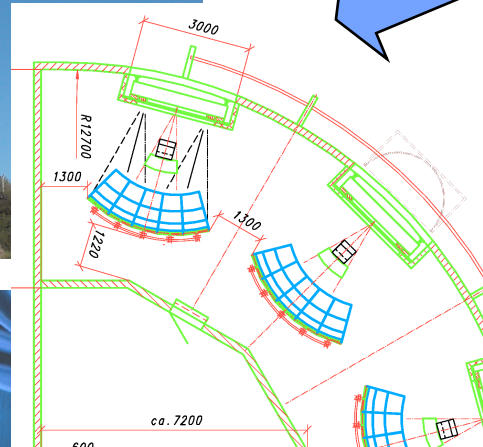


400 station in-fill 1mi spacing (2000 km²)

5 FD eyes – 39 telescopes

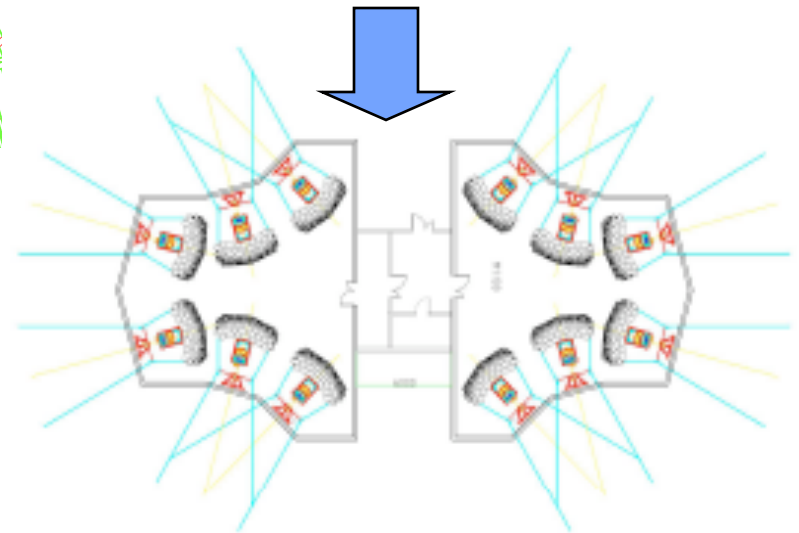
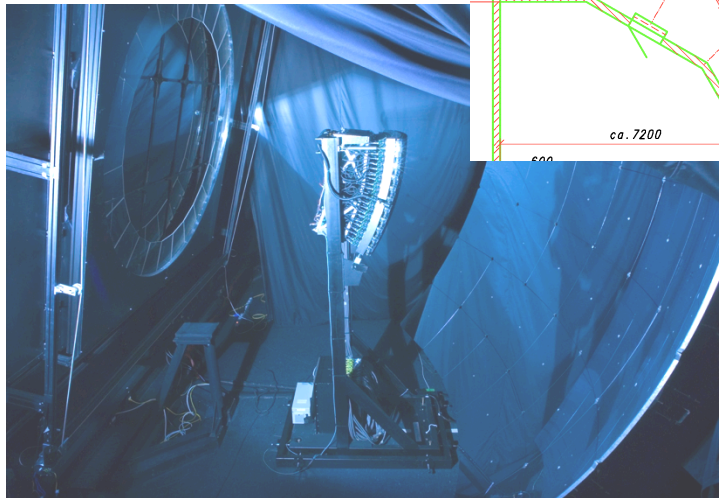


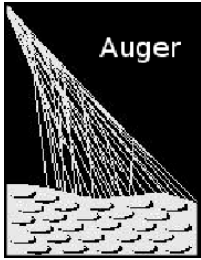
Features of Auger North Fluorescence Detector



**The Auger North FD
telescopes are same as
Auger South.**

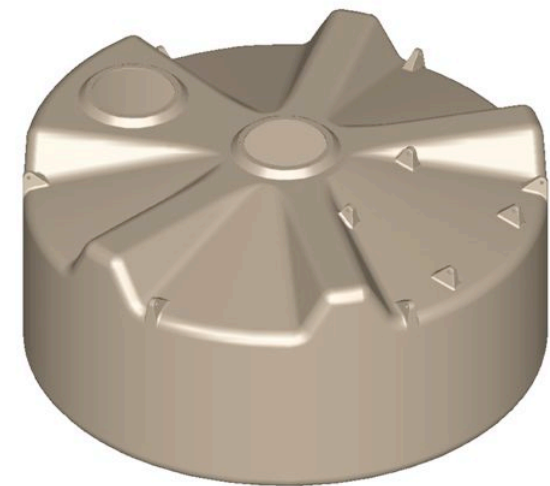
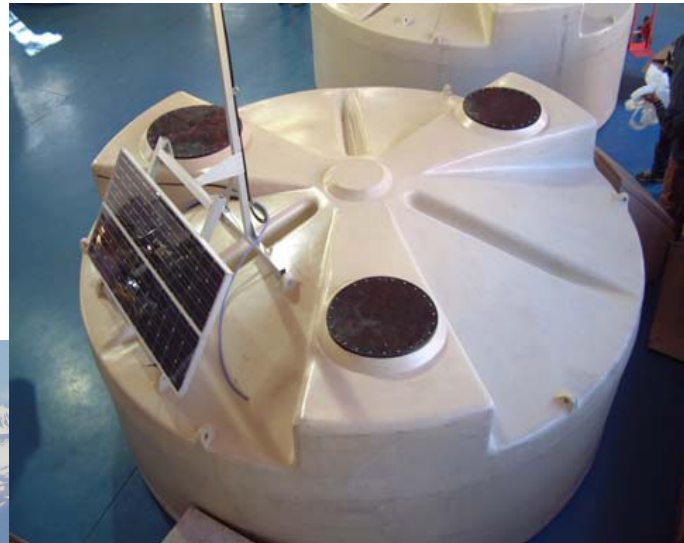
**The enclosure design is
simplified to reduce cost.**



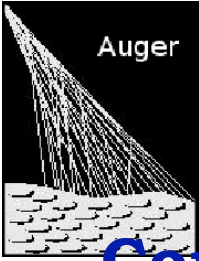


Features of Auger North Surface Detector

**Auger South
3 PMTs**



**Auger North
1 PMT
insulated**



Features of Auger North Infrastructure



Communications System

Auger South – Detector stations talk directly to one of four towers.

Auger North – Detector stations talk only to neighboring stations, relaying the data to central concentrators via multiple hops.

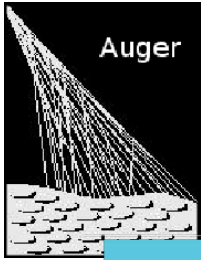
Campus Area



Malargüe



**Lamar Community
College**



The Auger Collaboration

91 Institutions, 463 Collaborators

 Argentina	 Australia	 Bolivia	 Brasil
 Czech Republic	 France	 Germany	 Italy
 Mexico	 Netherlands	 Poland	 Portugal
 Slovenia	 Spain	 United Kingdom	 USA
 Vietnam			

Argentina
 Australia
 Bolivia*
 Brazil
 Czech Republic
 France
 Germany
 Italy
 Mexico

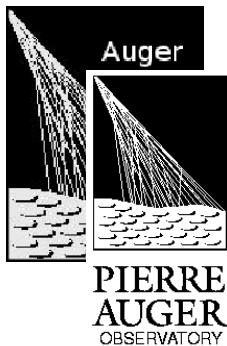
Netherlands
 Poland
 Portugal
 Slovenia
 Spain
 United Kingdom
 USA
 Vietnam*

* associate

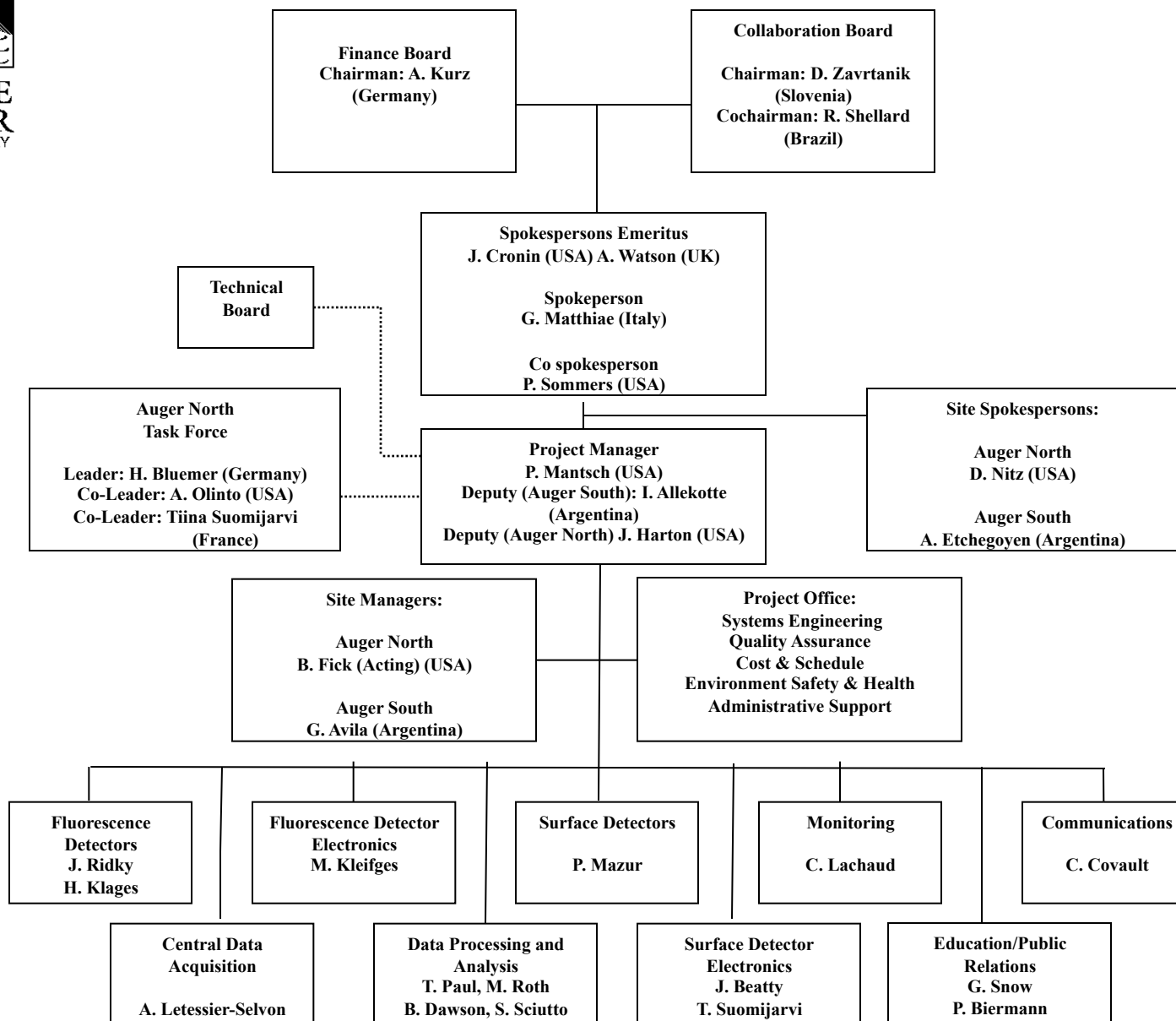
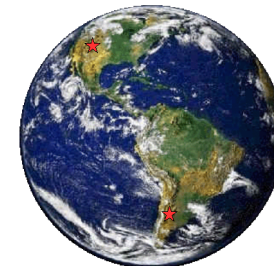
True International Partnership
- *by non-binding agreement* -

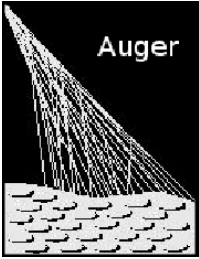
No country, region or
institution dominates





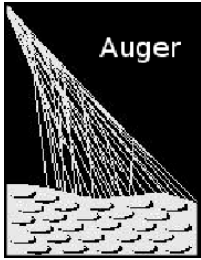
Auger Organization





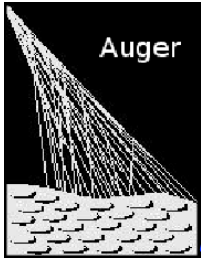
Estimated Construction Cost

<u>WBS</u>	<u>Activity</u>	<u>Total Project Cost (M\$)</u>
	AUGER NORTH Project	126.7
1.0	FLUORESCENCE DETECTOR	32.9
2.0	SURFACE DETECTORS	68.5
3.0	COMMUNICATIONS	6.8
4.0	CENTRAL DATA ACQUISITION	0.4
5.0	DATA PROCESS & ANALYSIS	1.1
6.0	SITE DEVELOPMENT	11.9
7.0	PROJECT MANAGEMENT	5.1



Time Line

<i>Year</i>	<i>Milestones</i>
2009-2011	Detector R&D, Finish Engineering Array (RDA)
2012	Campus: Complete Office & Assembly Buildings FD: Construct 1st 12-Telescope enclosure; Install Telescopes 1-6 SD: Procure Detectors 1-100; Install Detectors 1-50
2013	FD: Construct 2nd 12-Telescope enclosure; Install Telescopes 7-18 SD: Procure Detectors 101-1000; Install Detectors 51-400
2014	FD: Construct 1st 6-Telescope enclosure; Install Telescopes 19-30 SD: Procure Detectors 1001-2400; Install Detectors 401-1000
2015	FD: Construct remaining enclosures; Install Telescopes 31-39 SD: Procure 2401-3600; Install Detectors 1001-2500
2016	FD complete SD: Procure remaining detectors; Install Detectors 2501-4400



Funding



Auger South (\$54M):

European Countries - ~50%

Latin American Countries - ~25%

US - ~25%

Contribution:

80% in-kind

20% common fund.

Auger North (\$127M)

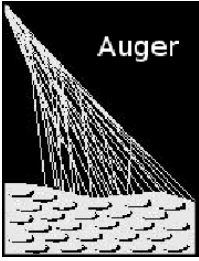
Current collaboration + possible new countries.

US Auger North Requests:

DOE \$20M

NSF \$20M

State of Colorado ~\$10M



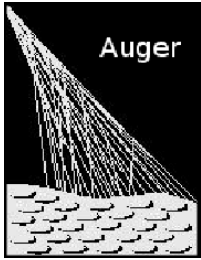
Auger at Fermilab

Physicists

Eun-Joo Ahn (Postdoc)
Ivone Albuquerque (Sabbatical)
Aaron Chou (Wilson Fellow)
Hank Glass
Carlos Hojvat
Peter Kasper
Fred Kuehn (Postdoc)
Paul LeBrun
Paul Mantsch
Peter Mazur

Our participation:

- **Project Management**
- **Data Analysis**
- **Surface Detector Design**
- **Data Mirror**
- **Calibration database**
- **Planning for Auger North**
- **FD/SD shifts at AS**
- **Airfly**

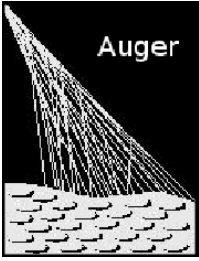


US Auger Groups



Argonne National Laboratory
Case Western Reserve University
Colorado School of Mines
Colorado State University, Fort Collins
Colorado State University, Pueblo
Fermilab
Louisiana State University
Michigan Technological University
New York University
Northeastern University
Ohio State University
Pennsylvania State University
Southern University
University of California, Los Angeles
University of Chicago
University of Nebraska
University of New Mexico
University of Wisconsin-Madison
University of Wisconsin-Milwaukee

More US institutions expected for Auger North



Fermilab and Auger North

Why Fermilab?

Leadership in physics at the Energy Frontier

Exceptional resources and experience in:

- Project Management

- Computing

- Engineering

Strong Analysis team (close ties to the University of Chicago)



The Pierre Auger Observatory

Auger North

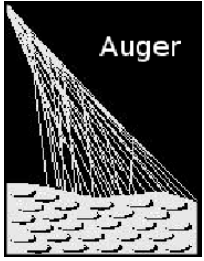
UNIQUE OBSERVATORY

To Discover the Sources of

Ultra High Energy Cosmic Rays

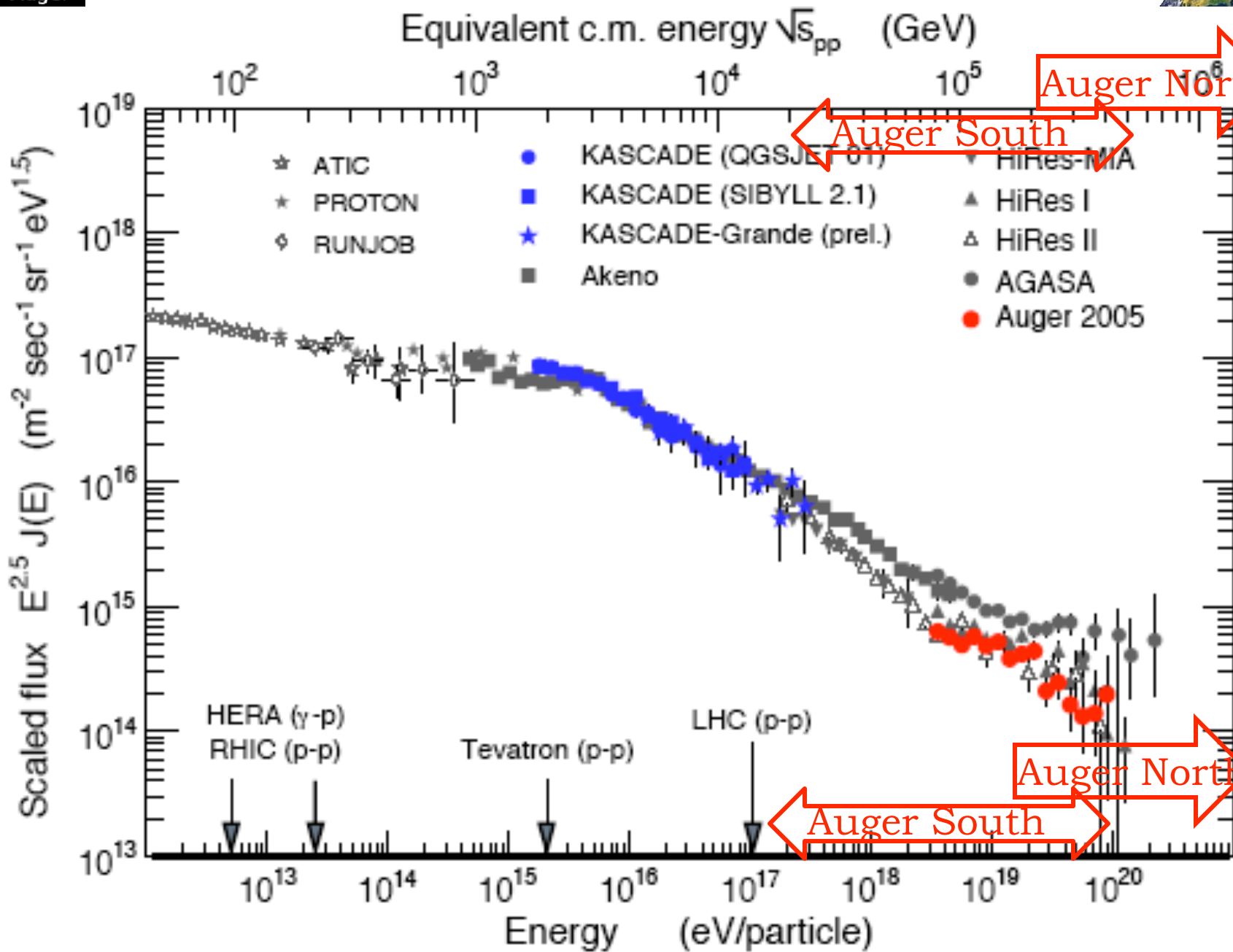
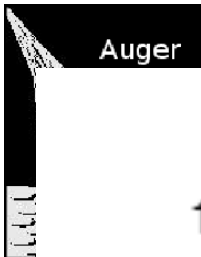
To Study Particle Interactions

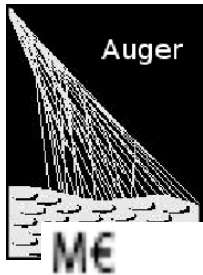
above 100 TeV CM



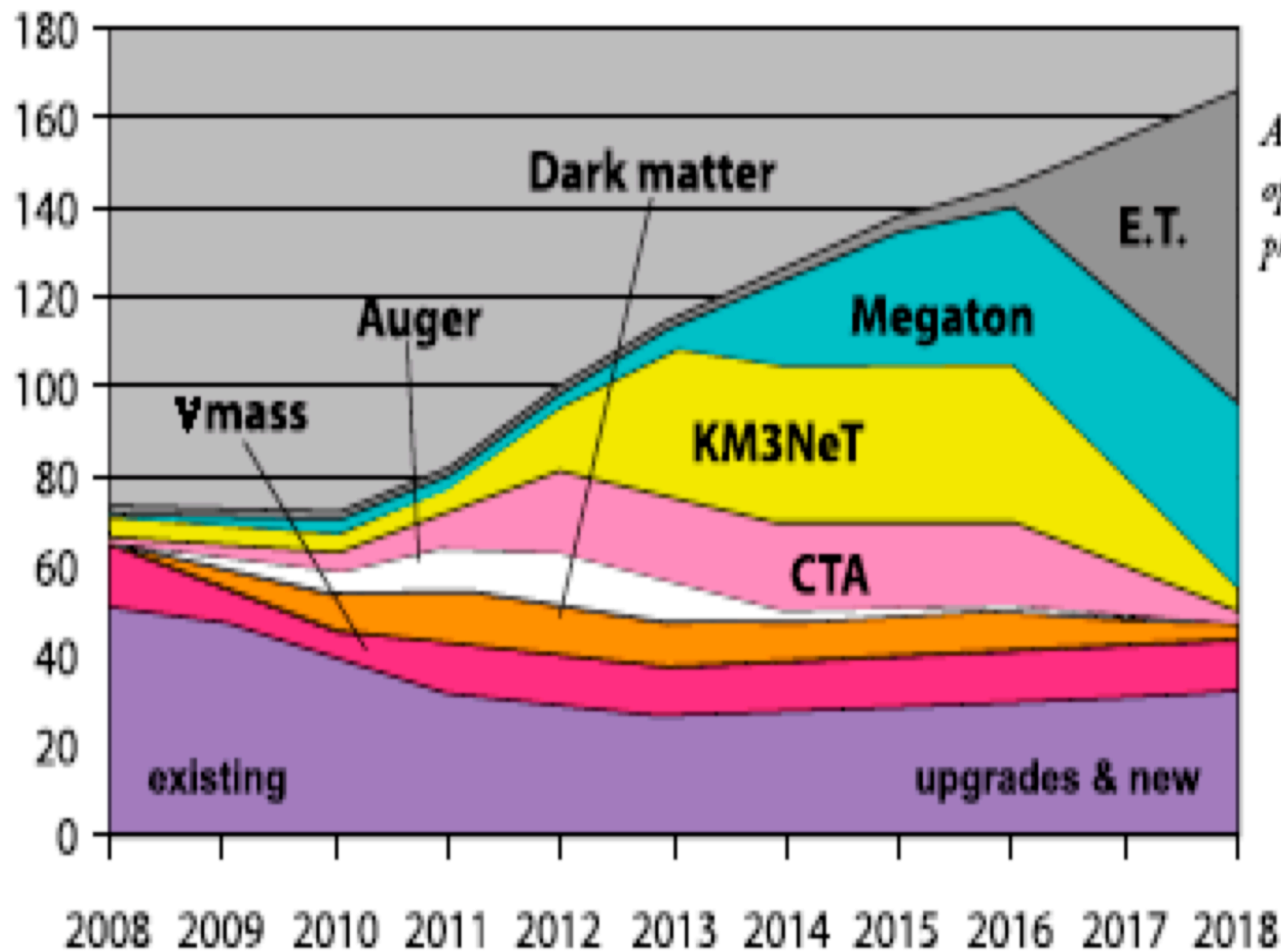
EXTRAS







ASPERA ROADMAP



A scenario for investment and operation cost of astroparticle physics in the ASPERA countries.